INFLUENCE OF PREPARTUM DIET TYPE ON COW PERFORMANCE AND SUBSEQUENT CALF PERFORMANCE

BY

THOMAS BAIN WILSON

THESIS

Submitted in partial fulfillment of the requirements
for the degree of Master of Science in Animal Sciences
in the Graduate College of the
University of Illinois at Urbana-Champaign, 2012

Urbana, Illinois

Adviser:

Assistant Professor Daniel W. Shike

ABSTRACT

INFLUENCE OF PREPARTUM DIET TYPE ON COW PERFORMANCE AND SUBSEQUENT CALF PERFORMANCE

Spring-calving, mature Angus, Simmental, and Simmental x Angus cows (n = 191) were utilized to evaluate the effects of prepartum diet type on cow and subsequent calf performance. Cows were blocked by BW and calving date into 16 pens and allotted to isocaloric, isonitrogenous dietary treatments: corn coproducts and ground cornstalks (COP) or ground hay (Hay). Treatment diets were fed from 90d prepartum to calving. All cows were fed a common diet postpartum. Cow BW and BCS were taken at beginning of feeding period, calving, and breeding. Calf BW was taken at birth and 56d intervals from the average calving date. Milk production was determined utilizing the weigh-suckle-weigh technique on d56 and d112. On d112, steers (n = 64) and non-replacement heifer calves (n = 23) were weaned and placed on a common feedlot diet with individual feed intake monitored using GrowSafe. Feedlot calves were harvested at a commercial facility when ultrasound 12^{th} rib fat thickness (BF) reached 1.2 cm. Initial cow BW and BCS were not different ($P > 0.92$). At calving, cow BW trended higher ($P = 0.08$) and BCS was greater ($P < 0.01$) for COP cows. For COP, trends for increased calf birth BW ($P = 0.06$) and calves born dead ($P = 0.08$) coincided with numerically lower unassisted births ($P = 0.13$). Hay fed cows also tended to be lighter ($P = 0.07$) at breeding with lower BCS ($P = 0.05$); nevertheless, overall conception rate was not different ($P = 0.83$). No differences ($P \geq 0.42$) in milk production were detected. Weaning BW, final BW, and days on feed were not different ($P \geq 0.19$); and as result, no difference ($P = 0.68$) in feedlot ADG was detected. Feedlot

DMI and G:F were not different ($P \geq 0.48$) across treatments. Calf health was monitored with no differences ($P \geq 0.71$) in mortality observed. No differences ($P \geq 0.45$) were detected for HCW, LMA, BF, marbling score, yield grade, or KPH. No differences ($P \geq 0.32$) in quality or yield grade distribution were observed. Prepartum cow diets, differing in energy source and protein type, formulated to be isocaloric and isonitrogenous do not affect performance and carcass traits of subsequent offspring.

Key Words: cow gestation fetal programming

To my late grandfather, Bain Wilson,
If I turn out to be half of the man you were, I will have done alright
I hope you would approve

ACKNOWLEDGEMENT

I would like to thank the members of my graduate committee: Dr. Daniel W. Shike, Dr. Dan B. Faulkner, and Dr. Douglas F. Parrett for their time and share of the financial support, guidance, and assistance in designing my research project and graduate program that I have received, and for their interest in recruiting me to the University of Illinois.

I would also like the staff at the Orr Beef Research Center and the Beef and Sheep Field Laboratory for making this research project happen. As graduate students, we sometimes feel that we alone are responsible for the success of a research project. This simply isn't true. I especially would like thank Mr. Tom Nash and Mr. Nathan Post for their efforts and hard work in coordinating and completing this research project. Thank you to Geri Goldberg for assistance on an innumerable number of occasions.

Next, I would like to thank Justin Adcock, Travis Meteer, and Keela Retallick for their assistance with this research project. They have spent countless hours assisting with the ultrasounding of calves or implementation of a weigh-suckle-weigh. I also value the assistance and friendship of the other members of the "beef group": Chris Cassady, Wes Chapple, Matt Duckworth, Adam Schroeder, Jacob Segers, and Lindsay Shoup.

Finally, I would like to thank all of my family. To my parents, Wayne and Deborah, thank you for realizing my potential before I realized it myself, and then giving me the tools to reach it. To my brother, Ben, thank you for you friendship and I am lucky to have you. And to my grandparents, thank you for your never-wavering love and support of my endeavors.

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER 1

LITERATURE REVIEW

Introduction

Feed costs have long been regarded as the primary input cost that must be managed in a beef cow operation. An economic analysis of commercial cow-calf producers conducted by Miller et al. (2001) from 1996 to 1999 utilizing 225 herd-year observations determined that 63% of total annual cow costs can be attributed to feed costs. Miller et al. (2001) further explained that feed costs account for over 50% of the variation in production costs between operations. It was also determined that there existed a difference of over $1.00/d·cow^{-1} in feed costs between high and low cost producers.

The time of year that typically accounts for the largest portion of annual feed costs is during the winter months. Braungardt et al. (2010) commented that winter was the most expensive time for cow-calf producers to maintain the herd as pasture becomes limited or because cows must be fed in dry lots. This is especially true for spring-calving herds as winter coincides with late gestation and early lactation; the period of time that cow nutrient requirements are at their maximum.

Hay Feeding

An often used method of providing supplemental feed to the cow herd is to provide ad libitum access to large round bales of hay. This is largely due to the ease of storage, handling, and management of feeding large round bales of hay. Despite this, offering ad libitum access to round bales of hay comes at great cost in the form of potentially substantial feeding loses. In a study that investigated restricting time of access to large round bales, Miller et al. (2007) determined that hay wastage by cows fed in fence-line hay feeders can be as high as 40%. This hay wastage represents increased input costs for cow-calf producers as hay wastage must be accounted for when assessing needs for stored feeds.

A method in which hay can be fed that minimizes waste is program feeding. Programmed feeding is a method that utilizes net energy equations to calculate the quantities of feed required for maintenance and a desired rate of gain (Galyean, 1999). He explained that when program feeding mature beef cows, dry matter intake is restricted to avoid excessive body condition and wastage of feed. Research has shown that limit feeding, when compared to ad libitum feeding, reduces visceral mass and as a result decreased maintenance requirements (Sainz and Bentley, 1997). Reduced maintenance requirements for program-fed beef cows could translate to performance advantages for limit-fed beef cows. Miller et al. (2007) poses that the most desirable method of feeding hay to beef cows would be feeding processed forage in a bunk. This method would not only reduce over consumption of forage but also reduce forage wastage. However, the additional equipment required for processing forage and bunk feeding remains cost prohibitive for many small and medium scale cow-calf producers.

Limit Feeding Corn

Hay is not as energy dense as alternate feedstuffs, such as concentrates, requiring greater quantities of dry matter to be consumed by cows to meet their daily energy requirements. Limit feeding high concentrate diets to cows is one method that has been used to minimize cow winter feed costs. This method of wintering beef cows was investigated when long term corn prices were approximately $2.00 per 25.4 kg (bushel). In 2012 corn is much more expensive; 3 year average corn price is approximately $6.00 per bushel with prices exceeding $8.00 per bushel.

Loerch (1996) investigated the efficacy of limit feeding corn based diets as an alternative to ad libitum feeding orchardgrass hay to cows during late gestation and early lactation. In order to quantify these effects, three experiments were conducted with limit-fed cows consuming approximately 5 kg of whole shelled corn, 1.2 kg of supplement, and 1kg of hay daily. Few off-feed issues were observed when cows were limit-fed. When summarizing all three experiments, Loerch (1996) concluded that performance for cows limit-fed corn based diets was similar to that of cows offered ad libitum access to hay. It was also noted that in two of the three experiments conducted; limit-fed cows had calves with significantly higher birth weights. The author posed that this increase in calf birth weight could be caused by an increased energy supply to the fetus as increased fetal glucose supply has been reported to increase birth weight in lambs. Despite the fact that calves from limit-fed cows were heavier, no increases in calving difficulty were observed. Radunz et al. (2010) also observed increased calf birth BW without increased dystocia rate when differing energy sources were incorporated into beef cow winter diets. In the study conducted by Radunz et al. (2010), ad libitum grass hay was compared to concentrate based diets, corn and dried distillers grains plus solubles (DDGS), which were limit-fed to cows during late gestation. Also when summarizing the three cow feeding experiments conducted by Loerch (1996), it was noted that calf weaning weight tended to be higher when cows were limit-fed corn based diets. Subsequent reproduction appeared to be increased by limit feeding concentrate diets. This trend for increased conception rates was thought to occur because of increased pre-breeding BW loss in hay-fed cows. Greater variation in BW change occurred in limit-fed cows. This phenomenon is discussed in feedlot cattle by Galyean (1999). When variability in BW is substantial within a pen, individuals are likely to under-consume or over-consume the targeted intake of feed; while average performance is as expected. The most striking difference in these two wintering systems was not in animal performance, but in daily feed costs. The economic analysis conducted at the time of publication determined that it cost nearly twice as much to winter cows using hay, valued at $80 per ton, when compared to limit feeding a corn based diet with corn valued at $2.00 per bushel. For the three cow-feeding experiments combined, the average daily feed costs were $0.78 and $1.41 for limit-fed cows and hay-fed cows respectively.

To follow up the work conducted by Loerch (1996), Schoonmaker et al. (2003) evaluated different beef cow wintering systems in two different experiments utilizing cows in late gestation and early lactation. The systems that Schoonmaker et al. (2003) evaluated were ad libitum feeding of orchardgrass hay, limit feeding a high concentrate diet similar to that fed by Loerch (1996), and grazing stockpiled orchardgrass forage. It was concluded that all three wintering systems evaluated can properly maintain acceptable cow performance. Unlike in the study conducted by Loerch (1996), Schoonmaker et al. (2003) observed no differences in calf birth weight or weaning weight. When comparing the ad libitum hay diet and limit-fed corn diets, limit feeding concentrates reduced daily feed costs by up to 50%. The average daily feed costs were again calculated with hay valued at $80 per ton and corn at $2.00 per bushel. When compared to ad libitum feeding of hay, grazing cows on stockpiled forage reduced feed costs by 10% to 48%. This great variation in the cost to graze stockpiled forage was attributed to differences in forage availability by year, subsequent added costs of pasture rental, and days of inclement weather that required more stored feeds to be fed.

Corn Coproducts

Description and Nutrient Composition

Since the previously discussed studies investigating limit feeding corn-based diets to cows were conducted, grain prices have increased substantially as a result of the growing ethanol industry. As a result, the practice of feeding alternative cost effective energy sources has gained momentum. Corn coproducts have increased in availability as a result of expansion of the ethanol industry and provide an excellent source of energy and protein when formulating beef cow rations.

The two corn coproducts of the greatest prevalence are distillers grains, a product of the dry grind process, and corn gluten feed (CGF), which is derived from the corn wet milling process. Distillers grains can be found in dry or wet form and with solubles (DGS) added. CGF is also commonly pelleted for ease of storage. The corn dry grind process essentially removes the starch from the corn kernel, further concentrating all other nutrients by approximately three times in the resulting distillers grains (Klopfenstein et al., 2008). Dried distillers grains plus solubles typically contain 30% crude protein (CP), 11% fat, 46% neutral detergent fiber (NDF), 0.26% calcium, and 0.83% phosphorus (NRC, 1996). A large proportion of the protein contained in DDGS is in the form of rumen bypass protein with the protein in DDGS being approximately 73% rumen undegradable protein (RUP; NRC, 1996). Klopfenstein et al. (2008) explains that this is largely attributed to the fact that zein, the primary protein found in corn, is only about 40% degraded in the rumen. Another reason for the high levels of escape protein in DDGS is because much of the protein found in the distillers solubles is derived from heated and denatured yeast cells that have been shown to be resistant to microbial degradation.

Corn gluten feed is a result of the corn wet milling process that fractionates the corn kernel much more completely than the dry grind process. Corn gluten feed is derived from the combination of two process streams in the corn wet mill. CGF is comprised mainly of the bran, or pericarp that surrounds the kernel, but also the steep liquor, rich in water soluble sugars and proteins, which is derived from water used to soak and swell the grain prior to fractionation (Green et al., 1987). The resulting coproduct is approximately 24% CP, 3% fat, 36% NDF, 0.07% calcium, and 0.95% phosphorus (NRC, 1996). When compared to DGS, CGF is lower in CP and fat as the proteins associated with the endosperm and oil-rich germ are removed through additional product streams. The protein found in CGF is also much more digestible in the rumen with a lower percentage escaping microbial degradation, as evidenced by the 25% RUP value listed in the NRC (1996).

Due to the substantial amount of corn bran found in both DGS and CGF, NDF provides most of the carbohydrate in these products (Klopfenstein et al., 2008). Klopfenstein et al. (2008) further explains that in situ and in vitro studies have shown that the cellulose in corn is highly and rapidly digested. This is in contrast to whole corn where the primary source of carbohydrate is starch. While these feedstuffs are an excellent source of highly digestible fiber, the NDF contained in corn coproducts cannot be expected to replace forage in diet of beef cattle due to the small particle size of corn bran in DGS and CGF. This is best evidenced by comparing the NDF and effective neutral detergent fiber (eNDF) values provided in the NRC (1996) for DDGS and corn silage containing 40% grain. DDGS contains 46% NDF and 4% eNDF while corn silage is listed at 45% NDF and 81% eNDF.

In a review of using DGS in the cattle feeding industry, Klopfenstein et al. (2008) stated that traditionally DGS were used almost exclusively as a protein source. This is a result of lower corn prices that had historically hovered around $2.00/bu. and limited availability of DGS prior to the expansion of the ethanol industry during the 1990's. With the growth seen in the ethanol industry, corn prices rose drastically while the production of corn coproducts was increased significantly; stimulating interest in feeding DGS and CGF by both the cow/calf and cattle feeding sectors. Klopfenstein et al. (2008) further states that, "Considering using a protein source as a feed energy source was a major paradigm shift."

Feeding Value of Corn Coproducts

A meta-analysis of five feedlot studies with DDGS inclusion of 10-40% of the diet concluded that DDGS had a greater feeding value than corn (Klopfenstein et al., 2008). The feeding value of DDGS was greatest when fed at 10% of diet dry matter, being 153% that of corn. As inclusion of DDGS increased, feeding value was reduced with DDGS having 100% of the value of corn when 40% was fed. As CGF is much lower in fat when compared to DGS, CGF has a feeding value much more similar to corn, but has been proven to be effective in replacing corn in the diets of feedlot cattle (Green et al., 1987). While conducting three trials involving finishing cattle fed CGF replacing either 23% or 46% of the corn in the diet, Green et al. (1987) observed that CGF had 87 to 100% the feeding value of dry rolled corn (DRC).

While numerous studies have investigated the feeding of corn coproducts, and their corresponding value as a corn replacement, to feedlot cattle; data involving the use of these products in forage based diets is generally much more limited. Loy et al. (2008) conducted an experiment in which beef heifers consuming grass hay were supplemented DDGS, DRC, or a mix of DRC and corn gluten meal (CGM) at 0.21% or 0.81% of BW. By manipulating the NE adjusters of the NRC (1996) model, it was determined that the DDGS supplements had 130% the energy value of corn when supplement was fed at 0.21% of BW. In agreement with the previously described meta-analysis involving feedlot cattle; as more DDGS were fed, feeding value decreased to 118% that of corn when fed at the higher level of 0.81% of BW. The corresponding total digestible nutrient (TDN) values for DDGS were 120% and 95.8% for the 0.21% and 0.81% supplement levels, respectively. This is in contrast to the NRC (1996) value of 88% TDN for corn and 88% TDN for DDGS.

Limit Feeding Corn Coproducts

With additional production and availability of coproducts, many producers have replaced corn with coproducts in beef cow diets. Due to their dense concentration of nutrients, it is necessary to limit feed corn coproducts in beef cow diets to prevent wasteful over-conditioning of the cow herd. Since the practice of feeding corn coproducts as an energy source is a relatively new one, few research trials evaluating their use at high inclusion rates in limit-fed beef cow diets have been conducted.

Comparing CGF and DDGS

Shike et al. (2009) conducted two experiments that evaluated the use of CGF and DDGS in the diets of lactating spring-calving cows. In experiment one, either CGF or DDGS were incorporated into a total mixed ration (TMR) with ground alfalfa hay at approximately 55% of total diet dry matter with diets formulated to be isocaloric and meet or exceed protein requirements. When cows were placed on treatment diets from calving until breeding, CGF fed cows lost more BW and tended to lose more BCS; resulting in trends for DDGS fed cows to be heavier and carry more body condition at breeding. CGF fed cows had greater milk production which coincides with a trend for increased calf average daily gain (ADG). Although the treatment diets were formulated to be isocaloric, Shike et al. (2009) suggested that there may be a difference in nutrient partitioning between the two diets as evidenced by the fact that the DDGS fed cows had less BW loss and decreased milk production when compared to CGF fed cows. This is in contrast to Kleinschmit et al. (2006) who observed increased milk production of dairy cows with DDGS when compared to a control diet. However, that study evaluated DDGS at an inclusion rates of 20% which is much lower than the approximately 55% DDGS fed by Shike et al. (2009). Two substantial differences between the CGF and DDGS diets were fat content, 3.0% and 5.8% respectively, and rumen protein degradability. It is unlikely that the difference in fat content was responsible for the depressed milk production observed with DDGS. Shike et al. (2009) references studies utilizing dairy cattle where increased dietary oils depressed milk fat levels but not overall milk production. It was concluded that the observed energy repartitioning may be best explained by the differences in protein degradability between CGF and DDGS. Previous work has shown that diets high in rumen bypass protein resulted in the repartitioning of nutrients toward maternal growth and away from milk production; although the mechanisms responsible for this are not understood. Despite the fact that CGF fed cows lost more BW over the course of the experiment, no difference in artificial insemination (A.I.) or overall conception rates were observed by treatment.

Corn Crop Residue

Identification of cost effective forages that match the nutrient profile of corn coproducts is necessary when utilizing these coproducts in beef cow diets. Poor quality forages such as cornstalks and wheat straw are low in protein and often fail to meet the cow's energy requirement. However, the high nutrient content of corn coproducts make them extremely complementary with low quality forages. Low quality forages can also serve to alleviate several dietary mineral concerns that are present when feeding corn coproducts. These forages are typically high in calcium, which is lacking in coproduct feeds, and low phosphorous that is typically fed in excess in diets containing corn-derived coproducts. In the Midwest, incorporating cornstalks are of particular interest due to vast acres of cropland that are planted in corn annually. Cornstalk residue represents a feedstuff that is already abundant and at a reduced cost when compared to hay. Coordinating the harvest of crop residues within the farm enterprise is often a challenge due to labor, equipment, weather, etc. Development of a cost effective method for delivering corn coproduct/crop residue diets may be prohibitive for smaller producers. When fed in fence-line feed bunks, it is often necessary to grind cornstalks in order to reduce orts and prevent dietary sorting. The added cost of grinding forage can be cost prohibitive for smaller producers who may find it more cost effective to feed whole crop residue bales in bale feeders.

Feeding Corn Coproducts with Ground Cornstalks

In order to evaluate the use of low quality forages and corn coproducts in limit-fed diets, Kovarik et al. (2009) compared a limit-fed ground cornstalks/ wet distillers grains plus solubles (WDGS) diet to an all forage diet fed ad libitum. The WDGS diet was mixed at a ratio of 70:30 of WDGS to cornstalks and then packed in a concrete bunker for 30 days; with cornstalks being ground through a 17.8 cm screen to facilitate better packing. At feeding, cornstalks were added to the bunkered mix to achieve the targeted ratio of 41:59 WDGS to ground cornstalks. The all forage control diet was comprised of 43% bromegrass, 34% cornstalks, and 23% alfalfa haylage. Treatment diets were formulated to be both isocaloric and isonitrogenous and were fed to non-lactating, non-pregnant cows for a period of 76 days. At the end of the feeding period, WDGS fed cows were significantly heavier than the all forage fed control cows with a tendency for cow

ADG to be higher for WDGS cows. Despite these differences in final BW, there was no difference in final BCS between treatments. WDGS fed cows were able to gain more BW while consuming less dry matter as dry matter intake (DMI) was 10.4 kg and 7.7 kg for control cow and WDGS cows, respectively. The authors predicted that the 4.9% fat content of the WDGS diet would result in decreased ADG as previous research has shown that corn oil supplementation has been shown to decrease NDF digestibility; however, this does not appear to have been the case. Kovarik et al. (2009) poses that the reason for lower BW gains by control cows was due to lower than expected DMI as predicted using the NRC (1996) model. To add to this, it was observed that control cows sorted their diet while WDGS cows did not, consuming all of the dry matter offered to them. Increased BW gains by limit-fed WDGS cows may also be attributed to a reduction in maintenance requirement caused by lower visceral masses observed in limit-fed animals (Sainz and Bentley, 1997). Limit feeding cows a ground cornstalks/WDGS diet was effective in maintaining dry, open beef cows without performance loses when compared to feeding an ad libitum forage diet.

Shike et al. (2009) conducted a second experiment that evaluated the use of ground cornstalks and either CGF or DDGS in limit-fed beef cow diets. Spring-calving, lactating cows were fed diets containing approximately 76% CGF or DDGS from calving until breeding. As with the previously discussed experiment conducted by Shike et al. (2009), diets were formulated to be isocaloric while meeting or exceeding protein requirements. These high corn coproduct diets resulted in a tendency for DDGS fed cows to lose more BW when compared to GCF cows, but no differences in final BW were detected. Unlike in the first study completed by Shike et al. (2009), no differences were detected in milk production. It is important to note; however, that numeric differences in milk production favored CGF as in the previous study.

Subsequent reproduction was not affected by the type of corn coproduct that was utilized in the wintering cow diet.

It was concluded by Shike et al. (2009) that corn coproducts can be included in limit-fed cow diets with ground hay or ground cornstalks at levels up to 75% of diet dry matter. When summarizing both cow feeding studies, DDGS and CGF resulted in variables differences in cow BW change and milk production with no effects on subsequent reproduction. Despite the observed variations in cow performance, both of the coproduct feeds evaluated resulted in acceptable cow performance when matched with either alfalfa hay or ground cornstalks.

Corn Coproduct Blends with Cornstalk Bales

As the ethanol industry continues to develop, additional corn coproducts other than typical DGS are being derived from the corn dry grind process (Braungardt et al., 2010). For example, further fractionation is being utilized to remove the oil-rich corn germ prior to starch fermentation, resulting in DGS that are higher in protein while with lower fat content relative to traditional DGS. Braungardt et al. (2010) evaluated the use of these modified corn coproducts in lactating beef cow diets through the use of coproduct blends. Corn coproducts evaluated were DDGS, high protein dried distillers grains (HP; 40% CP, 5.5% fat), and corn bran (13% CP). Three coproduct supplements consisting of approximately 6.6 kg DDGS, DDGS/corn bran blend, or corn bran/HP blend were fed to cows offered free-choice corn residue bales, with a fourth treatment group given ad libitum access to alfalfa mixed hay from calving until breeding. The three coproduct supplements were formulated to be isocaloric, meeting energy requirements for lactating cows; DDGS/corn bran and corn bran/HP supplements were also formulated to be isonitrogenous and meet protein requirement. The DDGS and hay treatments were not formulated to be isonitrogenous, but exceeded protein requirement. Dry matter disappearance was similar for the three coproduct diets as well as the control hay diet. Hay fed cows lost more BW over the feeding period. These differences in BW loss could be due to additional fat in the coproducts supplements or an energy repartitioning effect as a result of the increased escape proteins found in the coproduct treatments. This possible repartitioning effect was discussed by Shike et al. (2009) when DDGS cows experienced less BW loss when compared to CGF cows. Braungardt et al. (2010) also offered that while the hay fed in this experiment was greater than 61% TDN, a high concentration of 52% NDF may have limited hay DMI, thus resulting in greater BW loss when compared to coproduct fed cows. Change in BW was not different for cows fed the two corn bran supplements that were formulated to be isocaloric and isonitrogenous. No differences in milk production, calf ADG, or A.I. conception rates were reported.

Substantial differences existed in daily feed cost between the treatment diets evaluated by Braungardt et al. (2010). Corn bran supplements that were formulated to meet but not exceed nutrient requirements were more cost effective that the DDGS supplement; costing \$1.75 and \$1.94/cow$\cdot$d^{-1}, respectively. This cost difference was due to the varying prices for the coproducts used in this experiment with DDGS, HP, and corn bran being valued at \$137.08, \$182.28, and \$96.02 per 907 kg, respectively. The most considerable variation in daily feed cost was that between the coproduct/cornstalk fed cows and those fed hay. The average feed daily cost for the three coproduct treatment groups was \$1.81 versus \$2.80/cow$\cdot$d^{-1} for the cows given ad libitum mixed alfalfa hay. An economic analysis calculated a breakeven cost of \$85/907 kg (short ton) when corn residue is priced at \$55/907 kg, and coproducts priced as previously listed above. The price actually paid for alfalfa mixed hay was \$131.67/907 kg, much higher than the

$85/907 kg breakeven price. This high cost of feeding hay is brought into further focus when considering that these cows also lost more BW over the course of the experiment.

Comparison of Diet Delivery Methods

A second experiment was conducted by Braungardt et al. (2010) that evaluated wintering spring-calving lactating cows by supplementing corn residue bales with DDGS as before, incorporating DDGS at two different levels into a TMR with ground cornstalks, and a control of alfalfa mixed hay. In this second experiment, the non-TMR diets were similar to the DDGS and hay diets in the previously discussed study by Braungardt et al. (2010). The DDGS/ground cornstalks diets were limit-fed and formulated to be isocaloric and non-isonitrogenous; but did exceed protein requirements of lactating beef cows. The two DDGS/ground cornstalks diets were composed of DDGS at approximately 50% and 63% of DM and will be referred to as TMR and LowResTMR, respectively. As before, hay fed cows lost more BW than those fed corn coproducts, regardless of feeding method. The cows offered ad libitum corn residue bales had lower final BCS and greater BCS loss than either TMR or LowResTMR fed cows; but, no differences were observed in BW change. The authors noted that ad libitum corn residue cows did have lower bale dry matter disappearance than expected, possibly leading to greater BCS loss. These same cows also tended to have greater milk production, which would correlate to greater BCS loss. There appeared to be a difference in nutrient repartitioning between the three coproduct diets. Although the ad libitum residue and TMR diets were similar in composition, the LowResTMR had a greater inclusion of DDGS and consequently a higher percentage of CP in the form RUP. As previously discussed, significant levels of RUP in the diet has been shown to cause nutrients to be repartitioned toward maternal growth and away from milk production. Despite the tendency for differences in milk production, calf ADG was not affected by maternal diet. Hay fed cows tended to have lower A.I. conception rates. The authors hypothesized that these lower conception rates may be due to higher levels of unsaturated fatty acids or RUP in the three coproduct diets relative to the hay treatment. Suspecting improved reproduction rates as a result of increased dietary fat level is substantiated by the work of Bellows et al. (2001) who observed improved conception rates with increased level of unsaturated fats in the diets of beef heifers. The increased BW loss also likely contributed to lower conception rates in hay fed cows.

Calculated daily feed costs were in agreement with the first experiment conducted by Braungardt et al. (2010), with the hay diet costing an additional \$1.00/cow·d^{-1} relative to the three coproduct diets evaluated. An economic analysis was also conducted on the costs associated with delivering the treatment diets to herds of 50 to 300 cows. With herds of 50 or 100 cows, hand feeding DDGS supplement to cows provided access to corn residue bales was less expensive than when a tractor was used to deliver DDGS supplement, either TMR diet was fed, or when cows were fed hay. However, when a tractor was used to feed DDGS in herds of 50 cows, hay feeding became the most cost effective while both the TMR diets were the most expensive options. These differences in feed costs existed simply because the cost of equipment ownership was not spread over enough cows in smaller herds, as is the case in larger herds. As herd size increased beyond 100 cows, feeding DDGS supplements with a tractor and feed wagon became the most economically favored feed delivery method. Hay feeding was the most expensive winter feeding strategy, with both TMR diets being intermediate in cost. The added equipment costs associated with grinding forages necessary for wintering cows using TMR diets did diminish as herd size increased, making the TMR and LowResTMR diets more attractive for large-scale cow/calf producers due to ease of management when compared to feeding cornstalk bales and feeding supplements separately.

In summary of the two experiments conducted by Braungardt et al. (2010), wintering cows on DDGS and corn stalk diets leads to more desirable cow performance than feeding free-choice mixed alfalfa hay without any negative impacts on milk production, calf ADG, and subsequent reproduction. Economics favored feeding DDGS supplements to cows given ad libitum access to cornstalk residue bales while feeding free-choice hay, in most cases, result in the highest daily cow costs. Feeding cornstalks and DDGS diets via a TMR was more expensive than feeding DDGS separately, but becomes attractive in large beef cow operations due to potential time savings.

Concept of Fetal Programming

Maintaining proper cow nutrition during gestation has long been viewed as vital to the success of the beef operation, and at times can be a struggle for producers. Throughout the numerous and diverse regions of the United States, much work has been devoted to developing effective strategies for maintaining pregnant cows that still maintain a thin profit margin. It is widely recognized that getting cows into optimum condition prior to calving is necessary for a successful lactation and rebreeding; as when cows are in early lactation, it is much more difficult to add BW and body condition to ensure high conception rates. The role of proper prepartum nutrition gains added emphasis when the potential effects of maternal nutrition on the growing and developing fetus are taken into account. In beef cattle, alterations to prepartum nutrition have translated to differences in adiposity, BW, cyclicity, LM area, and marbling scores of resulting progeny (Du et al., 2010; Funston et al., 2010a).

The concept that maternal nutrition can have long-lasting, significant influences on the prenatal life of subsequent progeny is known as fetal programming (FP). This concept is based off of the principle that living creatures are plastic in their development as influences or stimuli at certain points during that development can cause permanent changes in body structure, function, or metabolism (Barker, 2012). The fetus is reliant on the flow of nutrients it receives from its dam through the placental membranes. Hence, the maternal environment is responsible for "programming" the growing and developing fetus for postnatal life.

Origins of the Fetal Programming Concept

The concept of FP applies to all mammalian species and has been written about extensively in humans (Barker, 2007a; Barker, 2007b; Barker, 2012). The origins of this theory are grounded in several historical human cohort studies that investigated the geographical prevalence of chronic diseases such as coronary heart disease, type-two diabetes, and hypertension (Barker, 2007b). These studies typically involve instances of short-term, geographically isolated food shortages occurring in developed countries where detailed health records of children born during these periods are taken throughout life. Several of the historical events that have been analyzed for potential FP effects are several food shortages in England and Wales early in the twentieth century, and the famines that resulted from the Nazi occupation of Europe; such as the well-documented famine experienced in Helsinki, Finland (Barker 2007a; Barker 2007b). It was observed that incidence of disease was elevated in children from specific geographic regions in which widespread food shortages were present during the time these children were conceived, born, or during infancy. Often these food shortages were also associated to different social classes within the same nation, reflecting differences in living conditions. Typically, increased prevalence of diseases such as coronary heart disease has been thought to be related to the rise in living conditions and prosperity following World War 2. Further analyses completed by these cohort studies have shown even stronger correlation to maternal experiences such as poor living conditions and food shortage while affected offspring were in utero (Barker, 2007b). People most apt to coronary heart disease and type-two diabetes later in life tended to grow slowly in utero, had small birth weights, remained so for the first two years of life, and then gained BW and body mass index rapidly (Barker, 2007a; Barker 2012).

Timing of Fetal Growth and Development

The FP concept further states that there are specific, and in some cases brief, time points during gestation that different organs or systems are developed. In general, fetal growth and development occurs in two stages. Many of the fetal systems are developed during the first two thirds of gestation. The majority of fetal growth occurs in the final third, or trimester, of pregnancy. Due to the great amount of fetal growth that occurs during the final trimester, dam nutrient requirement is increased substantially at this time. However, it is an oversimplification to believe that the developing fetus is supplied directly by the maternal diet during pregnancy (Barker, 2012). The fetus is indirectly dependent on nutrients by the maternal diet; but is directly supplied by the dam's stored nutrients and turnover of tissues. Thus, fetal nutrient supply is more closely tied to the long-term, or lifetime nutrition of the dam. When applied to beef production, the influence of long-term plane of nutrition, and often resulting body condition, potentially has as much of an impact on fetal development than the current diet provided to the cow.

Hierarchy and Trajectory of Growth and Development

If maternal nutrient flow is inadequate to fully support fetal growth and development, a hierarchy of priorities exists so that tissues are developed in order of importance. Barker (2012) states that brain growth is first in this hierarchy while the development of organs that are non-functioning in the womb, such as kidneys and lungs, are of lower priority. The delayed development of low-priority organs is done to protect the ones that are vital to further development of the fetus, but puts these low priority tissues at risk.

The conclusions drawn from the human cohort studies led Barker (2012) to hypothesize that FP effects were closely related to the fetus's trajectory of growth in utero. This growth trajectory is thought to be set at or around the time of conception based upon available maternal nutrient supply. Size at birth is a reflection of the fetal growth trajectory. A rapid growth trajectory is set by an abundant nutrient flow during early gestation with demand for maternal nutrition the greatest during late gestation. Alternatively, if a state of maternal undernutrition exists at time of conception, a slow rate of fetal growth would be expected. As previously discussed, a hierarchy of priorities for fetal growth and development exists. If a rapid trajectory of growth is set, a high demand for nutrients is set. Nutrient restriction later in development would challenge the ability of the dam to meet the requirements of all developing fetal systems. To overcome instances of brief undernutrition, the fetus has the ability to exhibit accelerated growth; also known as compensatory growth and should be very familiar to livestock producers. However, if nutrients are to be devoted to accelerated growth, their allocation to some other developmental action must be decreased as an inexhaustible flow of the nutrients across the placenta is not present. It is accepted that trajectory of fetal growth is faster in males. Thus, male fetuses could be more susceptible to adverse developmental consequences caused by undernutrition in utero. Barker reasons that this may be partially explain the shorter lives of men.

The Impacts of Fetal Programming on Beef Cattle Production

Application of the FP concept is not limited to the field of human health. This concept is applicable to multiple areas in the field of animal science. Momentum to explore FP has gained substantial momentum in the last several decades from applied cow/calf production systems to basic epigenetic research. Many experiments have been conducted using laboratory animals in controlled environments. A growing number of studies have utilized food animals such as swine or sheep. Much fewer studies have been conducted evaluating the FP concept in large scale cow/calf systems. Funston et al. (2010a) conducted a thorough review of previous FP research that can be applied to beef production. As one might expect, many of these studies centered on the cow/calf production cycle, but many long-lasting FP effects were recognized in the feedlot.

Placental Development

One often overlooked period of fetal development is early in the gestation period. This oversight is largely because relative to late gestation or early lactation, cow requirements are near their lowest. Despite this; adequate nutrition during early gestation is equally important because the developmental processes during this period serve to lay the groundwork for further growth and development to occur as has been previously discussed with fetal growth trajectory. One of the primary developmental processes to occur at this time is establishment of the placenta through which maternal nutrients flow. A bout of maternal undernutrition at this stage can hinder proper placental development, slowing fetal growth trajectory, thus potentially having adverse effects on the fetus later in gestation or postnatally. Vonnahme et al. (2007) investigated the possible FP effects nutrient restriction had on placental vascularity and indirectly on maternal nutrient flows. Beef cows were either fed to meet NRC (1996) nutrient requirements or nutrient restricted to lose BW from days 30 to 125 of gestation. At day 125, a portion of the cows were slaughtered and necropsied. Remaining nutrient restricted cows were then realimented to reach similar BW as control cows by day 250. At day 250, all remaining cows were slaughtered and necropsied. At day 125, few differences in placental vascularity were present. Contrary to this, following realimentation on day 250, significant differences in placental vascularity were observed. This restriction also had reaching effects on the fetus as fetal weight was reduced by maternal undernutrition.

Skeletal Muscle

The skeletal muscle system is one bodily system that is of obvious importance to beef cattle production. This system is of lower priority for maternal nutrient partitioning than other organs or systems like the brain and central nervous system. Thus, skeletal muscle is of greater risk to inhibited development at times of nutrient restriction. The fact that no net increase in muscle fiber number occur following parturition makes the proper development of fetal skeletal muscle extremely important. Du et al. (2010) outlines the process by which fetal skeletal muscle development occurs. Prior to development into specific cell types, or differentiation, a pool of pluripotent and later multipotent mesenchymal stem cells exists in embryonic and fetal tissues. Muscle fiber, myofibers, development occurs in in two waves during fetal development. In cattle, the primary wave occurs during the first two months following conception with a limited number of myofibers generated in this stage. The myofibers generated during this phase serve as a framework for myofibers to develop during the second wave of myogenesis. This secondary stage is thought to last from the second to eighth month of gestation and is when the majority of muscle fibers are formed. Consequently, any nutritional insults that were to occur during this second wave of myogenesis would have lasting, permanent effects on resulting calves. Fetal skeletal muscle matures during late gestation, around day 210 of gestation in cattle. Nutrient restriction after this point would result in minimal impact on muscle fiber number, but can significantly decrease muscle fiber diameter and mass. Greenwood et al. (2004) noted that progeny from nutrient restricted cows had reduced BW and hot carcass weight (HCW) relative to adequately fed cows. These differences were attributed to reduced muscle mass as a consequence of maternal nutrient restriction. Nutrient restriction from early to mid-gestation has also caused alterations in muscle fiber type with type two, oxidative fiber types being favored in lambs (Zhu et al., 2006). Altering myofibers type can have implications on potential for postnatal muscle growth, growth efficiencies, and carcass characteristics later in life.

Marbling

Development of marbling, or intramuscular fat, is of importance to the beef industry. The formation of intramuscular adipocytes occurs during fetal development. These adipocytes do not experience a high level of fetal growth, but do provide the base for accumulation of marbling later in life. For maximum marbling to be realized postnatally, differentiation of multipotent cells must be committed to adipocyte formation in utero as few undifferentiated cells exist following parturition. In the fetus, adipogenesis is initiated at approximately the fourth month of gestation. This time period partially overlaps with the second wave of myogenesis during mid-gestation providing a major opportunity for maternal nutritional insults or stimuli to effect stem cell differentiation (Du et al., 2010). Fibroblasts which form the connective tissue found in muscle also form at this time. The development of adipocytes in fetal muscle is linked to maternal dietary energy level as is the development of skeletal muscle.

Strategies to increase marbling early in life would be more effective than those that take place later in life; as evidenced by the dwindling number of multipotent stem cells as cattle mature. After 250 days of age, nutritional influences have little chance of increasing adipocyte development. At this point, marbling is increased only through the growth of pre-existing adipocytes. Early weaning has been utilized to offer nutritional stimuli for additional development of adipocytes in growing beef calves (Wertz et al., 2002). It has been shown that early-weaned calves immediately transitioned to a high concentrate diet, often with substantial levels of starch, have higher marbling scores than traditionally-weaned calves when compared at equal subcutaneous fat thicknesses (Shike et al., 2007). Nutritional stimuli targeted towards optimizing muscle adipocyte differentiation during fetal development theoretically could surpass early weaning in its ability to increase marbling in beef calves. However, effective strategies that are applicable to large scale cow/calf production have yet to be refined. Funston et al. (2010a) proposed that, ideally, management strategies would allow the cow to achieve an adequate level of body condition prior to being exposed to an environment in which nutrients are limited. Possibilities to achieve this could include early weaning or altering the time of breeding and subsequent parturition.

Impacts of Energy Type

Systems work conducted in sheep provides evidence that primary energy source of gestational diets can alter adiposity and muscle development in lambs. Radunz et al. (2011a) fed pregnant ewes ad libitum haylage or limit-fed either corn or DDGS starting in mid-gestation through lambing. Ewes were managed in such a way that similar BW gains were targeted for each dietary treatment. At lambing, lamb birth BW was greater for both corn and DDGS fed ewes when compared to haylage, agreeing with previous research comparing different winter diet types conducted in beef cattle (Loerch, 1996; Radunz et al., 2010). Post-weaning growth rate of lambs was not different among maternal dietary treatments. At slaughter, HCW did not differ by treatment but dressing percentage of lambs born to DDGS fed ewes was decreased when compared to corn and haylage fed ewes. Along with the decreased dressing percentage for DDGS lambs observed by Radunz et al. (2011b), longissimus muscle (LM) area and visceral fat stores were lowest for lambs born to DDGS ewes; culminating in a decreased percentage of boneless trimmed retail cuts. These data indicate that maternal diet type had substantial impacts on both adiposity and muscularity of offspring. These differences may likely be stimulated by the protein content of the respective treatment diets. Radunz et al. (2011a) formulated diets to meet or exceed NRC (1985) nutrient requirements for energy and protein; but, these diets were not isonitrogenous. Given the elevated CP content of DDGS, it is highly likely that ewe protein requirement would have been easily exceeded for limit-fed DDGS dams. Based solely on the finding of Radunz et al. (2011b), it is difficult to determine the exact time that FP effects took place during gestation since ewes were placed on treatment diets for approximately two thirds of gestation.

Neonatal Health

Skeletal muscle and adipose tissue are not the only systems that are modified through changing cow diets. There is evidence that the immune system is also subject to the concept of FP. Data derived from both cattle and sheep implies that nutrient restriction during pregnancy can affect the health of neonates. Trials investigating immune status of newborn lambs have found that maternal global nutrition status influences immunoglobulin transfer. Hammer et al. (2007) observed that lambs from under-nourished mothers had increased immunoglobulin transfer, and offspring whose mothers were over fed had decreased immunoglobulin transfer.

These findings cause one to hypothesize that these lambs born to undernourished dams were programmed to survive in a harsher environment than those developed with an ample nutrient supply. Despite increased immunoglobulin transfer, it does not appear that calves born to nutrient restricted dams are healthier as neonates. Calves born to cows that were restricted to 70% of NRC (1970) energy requirement have been found to experience increased rates of morbidity and mortality. When Corah et al. (1975) fed cows concentrate diets that either met NRC requirement or 65% of NRC (1970) requirement for the last 100 days of gestation, differences in pre-weaning calf health and weaning BW were observed. Calves born to cows fed low energy diets had 19% more incidence of scours and had reduced weaning weights. While nutrient restriction may lead to improved immunoglobulin uptake, this does not necessarily translate to healthier, thriftier calves.

Feedlot Health

Health of the neonate is not all that appears to be altered by nutritional state of the dam. Funston et al. (2010a) summarized research conducted with laboratory animals that may explain how early nutritional insults in utero may contribute to increased incidence of bovine respiratory disease (BRD). Undernutrition in rats has been observed to elevate blood pressure during the fetal phase and throughout life, altering lung vascularity. This altered lung vascularity increases susceptibility to respiratory disease. Increased incidence of BRD has serious economic ramifications as it represents the primary cause of feedlot mortality. When Larson et al. (2009) supplemented cows grazing dormant winter range with protein-based supplement; differences in feedlot health of subsequent steer progeny were detected. No differences in calves treated for instances of BRD or metabolic disorders were detected from birth to weaning; however, steers whose mothers were provided protein supplement were healthier in the feedlot, with fewer being treated from weaning until slaughter.

Late Gestation Protein Supplementation

Much previous work has investigated specific aspects of the beef production cycle or has tested potential FP effects in non-ruminants. Fewer studies have been conducted that investigated maternal diet and the lifelong effects of subsequent progeny. Scenarios exist in beef production systems when cow nutrition can result in altered performance of offspring. In general, undernutrition and overnutrition are the two primary opportunities for dam diet to impact growth and development.

Adverse effects of nutrient restriction on fetal growth have been previously discussed. In applied cow/calf systems, pregnant cows grazing low quality, dormant forages during winter is a common example of when this nutrient restriction can occur. This susceptibility to nutrient restriction is largely due to the sharp seasonal differences in forage growth and nutrient availability. Particularly in the western United States when grazing native grasses, it is common for nutrient requirements of pregnant beef cows to exceed those available through forage alone. To alleviate these shortcomings, cows are often supplemented with protein based supplements. Supplemental RDP not only increases the amount of protein available to the cow, but increases forage organic matter digestion, allowing her to more effectively utilize available carbohydrates (Olson et al., 1999).

Effects on Steer Progeny

Stalker et al. (2006) conducted a three year experiment that evaluated the effects of protein supplementation during late gestation on both cows wintered on native range pastures and subsequent steer progeny. In this experiment; cows were offered no supplement (NS) or the equivalent of 0.45 kg of 42% CP supplement/cow·d^{-1} fed 3 days per week (PS) for 90 days prior to the start of the calving season. During the calving season, all cows were maintained in a drylot and fed hay. Through the supplementation period, PS cows were able to maintain BW and BCS with NS cows losing both. These differences in BW and BCS persisted through breeding, but had no effects on conception rates. It is important to note that Stalker et al. (2006) also grazed the same cows on sub-irrigated meadows postpartum or fed hay in a drylot. However; no interaction for subsequent reproduction were detected between prepartum and postpartum dietary treatments. The authors were not especially surprised at this as they posed that the differences in BCS were not great enough that a lack of difference in conception rates should be unexpected. Prepartum supplementation did not affect postpartum interval from calving to conception or percentage of cows conceiving in the first 21 days of the breeding season. Research conducted by Richards et al. (1986) indicates that days to pregnancy are shorter in cows calving with a BCS of 5 or greater compared with cows with BCS of 4 or less. However, it appears that a calving BCS greater than 5 does not further improve reproduction. In the experiment conducted by Stalker et al. (2006), NS cows had a BCS of 4.7 at calving, which may be approaching the threshold at which additional BCS does not improve days to pregnancy.

Despite late gestation protein supplementation not influencing cow reproduction, resulting calves were impacted. Calves born to PS dams were born 3 days later in the calving season, but birth BW was not affected. This is contrary to Spitzer et al. (1995) who observed increasing birth BW as BCS at calving was increased from 4 to 6. Yet again, the differences between the PS and NS may not have been great enough to stimulate a difference in birth BW, as BCS was 5.2 and 4.7 for PS and NS cows, respectively. Although birth BW was not different, PS calves were heavier at weaning and had higher pre-weaning ADG. This response in weaning BW to gestational protein supplementation agrees with the findings of Beaty et al. (1994) where calf weaning BW was increased as CP in supplement fed during gestation elevated. Spitzer et al. (1995) observed no differences in adjusted 205 day weight of calves born to cows managed to calve at BCS of 4, 5, or 6. The authors posed that this was because weaning BW is more heavily influenced by milk production and not maternal bodily reserves at calving. Other findings that have more intensively examined maternal diet and concurrent fetal growth and development show that is not completely true. The most striking difference observed by Stalker et al. (2006) was the greater weaning percentage for cows on the PS dietary treatment. Corah et al. (1975) saw a similar reduction in weaning percent when heifers and 2-yr-old cows were fed energy-deficient diets for 100 days prior to the beginning of the calving season. Steer progeny from the two gestational treatments entered the feedlot where they were finished on a common diet and harvested when 12th rib backfat (BF) was visually estimated to average 1.3 cm for all steers. No differences by treatment were detected in feedlot ADG, DMI, or efficiency of gain. Carcass characteristics also were not influenced by prepartum treatment. In contrast to the findings by Stalker et al. (2006), Ciminski (2002) saw improved growth of calves from PS dams under similar conditions to the study conducted by Stalker et al. (2006). Stalker et al. (2006) offered an explanation of the difference in results from the two studies in that Ciminski (2002) weaned calves later in the year (November instead of early October). This later weaning date could have reduced maternal BCS, making the growing fetus more susceptible to adverse effects of undernutrition. This hypothesis is supported by the fact that NS cows used in the Ciminski (2002) and Stalker et al. (2006) experiments calved at BS of 4.4 and 4.7, respectively. An economic analysis concluded that when steer calves were sold at weaning, net returns of calves from the PS treatment were $25.38 greater; being driven by the observed differences in calf weaning BW and weaning percentage. As foreshadowed by similar feedlot performance and carcass characteristics, differences by treatment for net returns through the feedlot phase were minimal. When retaining ownership of calves from birth to weaning, net returns were increased by $45.76 when cows were supplemented during gestation. This difference can be attributed almost entirely to the greater percentage of calves weaned from the PS group.

Effects on Heifer Progeny

In an experiment conducted simultaneously to the one by Stalker et al. (2006), Martin et al. (2007) utilized the same herd and dietary treatments (PS and NS) to evaluate the potential FP effects that late gestation supplementation may have on heifer calves and their productivity when retained in the herd. The authors justified this study as little research has been conducted that correlated maternal nutrition to reproductive performance of female progeny. For example; Corah et al. (1975) observed that for heifer calves from nutrient restricted dams age at puberty was delayed by 19 days, but pregnancy rate was not measured. Martin et al. (2007) observed no differences by treatment on birth date or birth BW of heifer calves. This is in contrast to the findings of Stalker et al. (2006) in which average calving date of PS cows was 3 days later than NS cows. Martin et al. (2007) concluded that maternal undernutrition during the last trimester of gestation does not surely result in reduced birth BW as has been seen in previous research. Like Stalker et al. (2006), an increase in calf weaning BW was seen when cows were offered protein supplement. However; unlike Stalker et al. (2006), this BW advantage was maintained to time of first breeding, pregnancy diagnosis, and beginning of the second breeding season. When considering that these studies were conducted under similar conditions, there appears to be an interaction between mature BW and maternal nutrient status. Steer final BW was not different by treatment; yet, heifer progeny had persistent BW differences by treatment at multiple time points. This may be a result of the increased fetal growth trajectory for male fetuses. If true, female fetuses would require fewer nutrients to achieve an equivalent level of fetal growth; and when provided with same flow of maternal nutrients, female fetuses would have the potential for further growth and development.

No effects of maternal nutrition were detected for the percentage of heifers cycling prior to the breeding season or for age at puberty. As previously mentioned; Corah et al. (1975) observed delayed puberty in heifers whose mothers had been energy-restricted to 65% of NRC (1970) requirement for 100 days prior to predicted calving date. It was posed that the likely cause for not seeing delayed estrus was the only moderate negative energy balance of NR cows when compared to the significant energy restriction imposed by Corah et al. (1975). Despite no treatment differences for age at puberty or the percentage of heifers cycling at the beginning of the breeding season, significantly more heifers from PS dams calved within the first 21 days of the calving season; 77% and 49% for PS and NS respectively. Differences in overall pregnancy rates were also substantial, but not as dramatic as for calving distribution, PS and NR heifers conceiving at 93% and 80%, respectively. The authors commented that the period that nutritional treatments were applied, late gestation, corresponds with the ovarian folliculogenesis and endometrial gland development in the fetus (Gray et al., 2001; Rhind et al., 2001). Thus, it appears that a moderately negative energy balance during late gestation potentially has deleterious effects on the fertility of heifer progeny integrated into the cow herd.

Protein Supplementation with Crop Residue Grazing

Another commonly used management tool by cow/calf producers is to graze cows on corn crop residue (CR). As previously discussed, CR is in great supply in the Midwest after the fall corn harvest. Grazing CR represents an economical alternative to feeding harvested and stored forages to cows in the drylot. Quality of CR is greatest at time of corn harvest and declines over the winter (Klopfenstein et al., 1987). This decline in quality is closely tied to the selective nature in which cattle graze cornstalks. Cattle tend to eat grain remaining in the field first, then the finer corn leaves and husks secondly, and leaving low quality cornstalks last. This decline in crop residue quality often necessitates that cows grazing cornstalks be supplemented later in the cornstalk grazing season.

Effects on Steer Progeny

Larson et al. (2009) conducted a three year experiment that sought to investigate the influences of different winter grazing strategies and protein supplementation in spring-calving herds on performance of both cows and subsequent feedlot steers. To do this, dietary treatments were arranged in a 2 x 2 factorial arrangement in which cows were grazed on winter range (WR) or CR and offered no supplement or the equivalent of 0.45 kg per day of 28% CP supplement fed 3 times weekly. All dietary treatments were applied for approximately 90 days prior to the start of the calving season. Cows wintered on CR were heavier with greater BCS than cows grazed on WR prior to calving. This is likely due to the superior quality of the CR early in the grazing period. In agreement with Stalker et al. (2006) cows offered PS had increased BW when compared to NS cows. Calving date for NS cows grazed on WR was 5 days later when compared to all other treatment groups. Larson et al. (2009) posed that this may have been a cumulative effect of BW loss and ensuing delays in conception as cows were maintained on the same treatment for all three years of the experiment. This argument is strengthened by the fact that 16% fewer WR-NS cows calved in the first 21 days of the calving season when compared to all other treatments. This finding contradicts those of Stalker et al. (2006) in which PS cows calved later than NS cows; but, it is important to note that cows on that study were alternated between PS and NS groups each year. Advantages in cow BW and BCS for CR and PS were maintained through pre-breeding. However, at weaning cow BW and BCS were not affected by supplementation with CR cows being heavier but having similar BCS as cows previously maintained on WR.

Milk production was estimated via the weigh-suckle-weigh technique (WSW; Boggs et al., 1980) in May and at weaning in late November. In May, CR cows tended to have greater milk production than NR cows with this trend becoming significant at weaning. This agrees with Corah et al. (1975) who found that cows had greater milk production with increasing energy level during late gestation. No effect of protein supplementation on milk production was detected. Calf birth BW was greater when dams were wintered on CR compared to WR while also tending to be heavier with supplement. This response in birth BW is interesting as no differences were seen in the same herd with protein supplementation (Stalker et al., 2006; Martin et al., 2007). However, this does agree with the findings of Spitzer et al. (1995) as cows calving in greater BCS had heavier calves. It was observed that supplementation increased calf BW in May when cows were maintained on WR, but not CR, indicating a FP effect of maternal nutrient status. It would appear that calf efficiency was improved when cows were more nutrient restricted, experiencing postnatal compensatory gain. It is unlikely that this effect was confounded by milk production, as no differences by supplement strategy were detected for milk production. Unlike the substantial difference detected by Stalker et al. (2006), weaning percentage was not influenced by either winter grazing or CP supplementation.   Calf weaning BW was greater for calves form PS than NS cows and is in agreement with previously conducted gestational supplementation studies.

Unlike the study conducted by Stalker et al. (2006), dietary treatments had long-term carry-over influences on the performance of feedlot bound progeny. This is highlighted by the fact that WR-NS calves were lighter than WR-PS steers entering the feedlot with these BW differences remaining at time of re-implanting. Winter grazing system had no lasting effects on feedlot ADG, but steers from PS dams tended to experience increased ADG than those from the NS group. A trend did exist for PS steers to have higher DMI; but gain efficiency was similar between PS and NS as ADG and DMI trended in the same direction. When comparing winter grazing systems, calves whose mothers were grazed on upland WR pastures were lighter at slaughter. In contrast to Stalker et al. (2006), PS resulted in heavier HCW relative to NS. Neither grazing system nor protein supplementation had any effects on BF, LM area, or yield grade (YG). Although subcutaneous fat thicknesses were similar across all treatments, intramuscular fat deposition was altered by maternal nutrition. Steers from supplemented cows had increased marbling, equivalent to approximately half of a USDA quality grade (QG), and as a result, percentage of calves grading low choice or better and average choice or better was improved. This QG advantage for steers born to PS cows was even greater if dams were grazed on CR. These data indicate that maternal nutrition can result in altered adiposity when maternal nutrition is enhanced during late gestation. Smith and Crouse (1984) determined that glucose is the preferred substrate for intramuscular adipocytes. Larson et al. (2009) reasoned that enhanced nutrition through concentrates, the grain portion of CR or supplement, increased insulin and glucose uptake or increased the supply of glucogenic amino acids available to the cow; thus, having a trickle-down effect on the fetus. The fact that Stalker et al. (2006) did not see a marbling response to PS under similar conditions may be a result of the differences in supplement offered to cows between the two studies. Stalker et al. (2006) fed a 42% CP supplement that was 31% RUP while the supplement used by Larson et al. (2009) was 28% CP and 48% RUP. It may be possible that increased RUP concentration in the supplement fed by Larson et al. (2009) changed amino supply or glucose production, stimulating preadipocyte development in the fetus. However, RUP from supplement was similar for both studies. The increase in carcasses grading choice without a simultaneous increase in YG resulted in an additional $47 of carcass value over steers from NS cows. An alternate theory for the marbling enhancements posed by Larson et al. (2009) revolves around the previously discussed differences in steer post-weaning health. As fewer calves from PS cows were treated for BRD during the finishing phase, it was reasoned that enhanced health lead to improved QG. The authors cited several studies in which treatment for BRD and the presence of lung lesions decreased quality grade (Gardner et al., 1999; Busby et al., 2004).

An economic analysis conducted by Larson et al. (2009) concluded that while cow and calf performance were enhanced with PS, this is not the most cost-effective strategy in all situations. When sold at weaning, the main effect of PS when compared to NS was a $16 reduction in net returns per steer. Larson et al. (2009) saw little advantage to supplementing cows grazing CR if calves were marketed at weaning. This is evidenced by the fact that steer calves from CR-NS cows received an average of $35 more per head than all other treatment groups. However; when just comparing calves from mothers that were maintained on WR, supplementation added $48 additional value to calves when sold at weaning.

Effects on Heifer Progeny

Funston et al. (2010b) conducted a simultaneous study to the one by Larson et al. (2009) that evaluated the dietary treatments of WR, CR, PS, and NS on heifer progeny that were retained in the cow herd. Supplemented cows calved 4 days earlier in the calving season than NS cows with grazing system having no effect on calving date for female progeny. In contrast to this, Larson et al. (2009) saw a trend for WR cows to calve later. Calf birth BW was elevated when cows grazed CR while supplementation treatment did not influence heifer calf birth BW. Larson et al. (2009) observed a trend for increased birth BW with PS; indicating a sex effect of PS on birth BW. As with previous research, weaning BW was greater when cows were grazed on CR, and lowest for heifers from WR-NS cows. The reduced BW observed for heifers born to WR-NS cows was maintained through to first calving and the start of the second breeding season. This led the authors to conclude that if cows are to be wintered on native range pastures, protein supplementation is necessary to achieve optimal production from progeny of either sex. Prior to breeding, heifers were individually fed for a period of 85 to 92 days. During this period, heifers from CR-PS cows had decreased ADG and G:F than heifers from any other treatment. The authors posed that this may represent increased efficiency by heifers from cows that were subject to varying levels of nutrient restriction during late gestation. However, this is contrary to the fact that no difference by treatment for ADG was detected from weaning to breeding.

When investigating luteal activity of these heifers, Funston et al. (2010b) observed that heifers gestated by PS cows reached puberty at a younger age when compared to NS heifers; which was contrary to the finding of Martin et al. (2007). Winter grazing system did not influence age at puberty. Age at puberty was also found to be independent of BW, as BW at first puberty was similar for all treatments. Funston et al. (2010b) posed that this difference in age at puberty means that the intrauterine environment, as determined by maternal nutrient flow, impacts prenatal development of the female reproductive tract. This difference for age at puberty between supplement groups was followed by a trend for decreased pregnancy rates in heifers whose mother had not received PS. At first calving, calving date, calf birth BW, and percentage of calves born in the first 21 days of the calving season was similar among treatment groups.

The studies conducted by both Larson et al. (2009) and Funston et al. (2010b) reveal that not only cow performance, but also that of subsequent progeny can be improved not only by PS but by grazing alternate forages such as CR. Multiple differences existed when fetuses of different sexes were developed under similar conditions. These differences may be the result of differences of fetal trajectory of growth between male and female fetuses.

Improved Grazing During Mid-Gestation

Much previous work investigating the effects of maternal nutrition on resulting progeny has been conducted during late gestation. This has been done for fairly obvious reasons. This is when cow nutrient requirements are at their greatest to accommodate the rapid fetal growth that occurs during this period. Also, dependent upon calving date, late gestation often is the period of time when the cow/calf producer is most responsible for providing a large proportion of the cow's nutrient supply with stored feedstuffs. But, it has been firmly established that maternal nutrition during mid-gestation has equal or greater influence on the developing fetus. However, as cows are often maintained on pasture and require little supplemental nutrition during this time, maternal nutrition during mid-gestation is often difficult to manipulate in applied beef production systems.

Underwood et al. (2008) conducted a study with the objective of investigating the influence of improved maternal nutrition during mid-gestation on the growth and carcass characteristics of resulting steer progeny. Beginning at either day 120 or 150 of gestation, cows were grazed on either native range (NR) or irrigated, improved pastures (IP) for a period of 60 days. Steers had similar BW upon being received into the feedlot and placed on a common diet. Underwood et al. (2008) observed that steers born to NR dams had deceased feedlot ADG, lower total BW gains, and lighter HCW. The authors commented that this is in agreement with lamb and rat pup data in which mothers were placed on a low plane of nutrition during mid-gestation. Upon collection of carcass data, it was observed that LM area and semitendinosus weight were similar for both treatments. The apparent parallel in muscle mass between the two treatments is perhaps a reflection on the time during gestation that maternal nutritional manipulation occurred. Grazing cows on IP resulted in greater BF, similar KPH, and similar marbling score in subsequent feedlot steers. This finding is supported by those of Underwood (2007) where steers resulting from cows on a low plane of nutrition tended to have increased subcutaneous fat at the 12^{th} rib and increased fat as a percentage of the 9-10-11 rib section. When commenting on the work of Underwood et al. (2008), Funston et al. (2010a) hypothesized that this difference in subcutaneous fat may have been due to the higher quality and digestibility of IP pasture. This should result in an increased level of acetate production for the cow. Smith and Crouse (1984) determined that acetate is the primary substrate used by subcutaneous adipocytes. It could be possible that grazing cows on IP increased the fetal acetate supply, increasing the recruitment of undifferentiated mesenchymal stem cells to the formation of fetal adipocytes. This hypothesis was advanced after further investigation of subcutaneous adipose tissue sections. Steers gestated on IP tended to have a greater number of subcutaneous adipose cells per field of view when light microscopy was used. No differences in average adipocyte diameter were detected. Shear force was reduced for steers whose mothers were grazed on IP, indicating improved tenderness. This could indicate altered collagen development as result of the timing at which maternal nutrition was manipulated. This study indicates that maternal nutrition during mid-gestation can have reaching effects on subsequent steer progeny. It is important to note that these treatment differences were enacted in a relatively short period of 60 days, indicating that the fetus is highly sensitive to nutritional changes at this time of development.

Summary

Feed costs represent the greatest cost to beef producers when maintaining the cow herd through winter. Traditionally, hay has been used to winter beef cows; but this represents the most cost-effective wintering system for only the smallest of herds. When commodity prices were lower, limit feeding corn diets to beef cows during gestation and lactation represented an effective and more economical option than feeding hay ad libitum. In recent years, corn coproducts such as DGS and CGF have increased in abundance as a result of the rapid expansion of the ethanol industry. These feedstuffs represent an excellent source of energy and protein that often has equal or greater feeding value in corn when incorporated in the diets of ruminants. When incorporated into limit-fed beef cow diets, with multiple forage sources, corn coproducts have proven to be effective for maintaining condition of beef cows.

The concept of FP has been derived by the study of incidence of chronic disease in humans; then further investigated using many different mammalian species. Experiments investigating the FP effects of maternal plane of nutrition have determined that maternal plane of nutrition at different period during gestation can affect placental, muscle, and adipose tissue development. Research has also indicated potential FP influences on the health and fertility of progeny. For practical reasons, nutrition during late gestation has been studied most extensively in applied beef production systems, but research in this area is far from being conclusive. Management strategies that have been investigated include supplementation and improved grazing to elevate maternal nutrient status and grazing crop residues. It appears that maternal nutritional manipulation has substantial potential to impact fetal development during mid-gestation. Research has shown that cow nutrition can result in enhanced performance of resulting progeny; however, these effects and the underlying mechanisms are not fully understood.

Literature Cited

Barker, D. J. P. 2007a. Obesity and early life. Obesity Reviews. 8 (Suppl. 1):45-49.

Barker, D. J. P. 2007b. The origins of the developmental origins theory. J. Intern. Med. 261:412-417.

Barker, D. J. P. 2012. Developmental origins of chronic disease. Public Health. 126:185-189.

Beaty, J. L., R. C. Cochran, B. A. Lintzenich, E. S. Vanzant, J. L. Morrill, R. T. Brandt, Jr and D. E. Johnson. 1994. Effect of frequency of supplementation and protein concentration in supplements on performance and digestion characteristics of beef cattle consuming low-quality forages. J. Anim. Sci. 72:2475-2486.

Bellows, R. A., E. E. Grings, D. D. Simms, T. W. Geary, and J. W. Bergman. 2001. Effects of feeding supplemental fat during gestation to first-calf beef heifers. Prof. Anim. Sci. 17:81-89.

Boggs, D. L., E. F. Smith, R. R. Schalles, B. E. Brent, L. R. Corah, and R. J. Pruitt. 1980. Effects of milk and forage intake on calf performance. J. Anim. Sci. 51:550-553.

Braungardt, T. J., D. W. Shike, D. B. Faulkner, K. Karges, M. Gibson, and N. M. Post. 2010. Comparison of corn coproducts and corn residue bales with alfalfa mixed hay on beef cow-calf performance, lactation, and feed costs. Prof. Anim. Sci. 26:356-364.

Busby, W. D., D. R. Stohbehn, P. Beedle, and L. R. Corah. 2004. Effect of postweaning health on feedlot performance and quality grade. A.S. Leaflet R1855. Iowa State Univ., Ames.

Ciminski, L. A. 2002. Weaning date and protein supplementation effects on cow/calf productivity. MS Thesis, Univ. Nebraska, Lincoln.

Corah, L. R., T. G. Dunn, and C. C. Kaltenbach. 1975. Influence of prepartum nutrition on the reproductive performance of beef females and the performance of their progeny. J. Anim. Sci. 41:819-824.

Du, M., J. Tong, J. Zhao, K. R. Underwood, M. Zhu, S. P. Ford and P. W. Nathanielsz. 2010. Fetal programming of skeletal muscle development in ruminant animals. J. Anim. Sci. 88:E51-E60.

Funston, R. N., D. M. Larson, K. A. Vonnahme. 2010a. Effects of maternal nutrition on conceptus growth and offspring performance: Implications for beef cattle production. J. Anim. Sci. 88:E205-E215.

Funston, R. N., J. L. Martin, D. C. Adams, and D. M. Larson. 2010b. Winter grazing system and supplementation of beef cows during late gestation influence heifer progeny. J. Anim. Sci. 88:4094–4101.

Galyean, M. L. 1999. Review: Restricted and programmed feeding of beef cattle — definitions, application, and research results. Prof. Anim. Sci. 15:1-6.

Gardner, B. A., H. G. Dolezal, L. K. Bryant, F. N. Owens, and R. A. Smith. 1999. Health of finishing steers: Effects on performance, carcass traits, and meat tenderness. J. Anim. Sci. 77:3168–3175.

Gray, C. A., F. F. Bartol, B. J. Tarleton, A. A. Wiley, G. A. Johnson, F. W. Bazer, and T. E. Spencer. 2001. Developmental biology of uterine glands. Biol. Reprod. 65:1311-1323.

Green, D. A., R. A. Stock, F. K. Goedeken and T. J. Klopfenstein. 1987. Energy value of corn wet milling by-product feeds for finishing ruminants. J. Anim. Sci. 65:1655-1666.

Greenwood, P. L., H. Hearnshaw, L. M. Cafe, D. W. Hennessy, and G. S. Harper. 2004. Nutrition in utero and pre-weaning has long term consequences for growth and size of Piedmontese and Wagyu-sired steers. J. Anim. Sci. 82(Suppl. 1):408. (Abstr.)

Hammer, C. J., K. A. Vonnahme, J. B. Taylor, D. A. Redmer, J. S. Luther, T. L. Neville, J. J. Reed, J. S. Caton, and L. P. Reynolds. 2007. Effects of maternal nutrition and selenium supplementation on absorption of IgG and survival of lambs. J. Anim. Sci. 85(Suppl.1):391. (Abstr.)

Kleinschmit, D. H., D. J. Schingoethe, K. F. Kalscheur, and A. R. Hippen. 2006. Evaluation of various sources of corn dried distillers grains plus solubles for lactating dairy cattle. J. Dairy Sci. 89:4784.

Klopfenstein, T., L. Roth, S. F. Rivera, and M. Lewis. 1987. Corn residues in beef production systems. J. Anim. Sci. 65:1139-1148.

Klopfenstein, T. J., G. E. Erickson and V. R. Bremer. 2008. Board-Invited Review: Use of distillers by-products in the beef cattle feeding industry. J. Anim. Sci. 86:1223-1231.

Kovarik, L. M., M. K. Luebbe, R. J. Rasby, and G. E. Erickson. 2009. Limit feeding beef cows with bunkered wet distillers grains plus solubles or distillers solubles. Univ. Nebr. Beef Rep. MP 528.

Larson, D. M., J. L. Martin, D. C. Adams, and R. N. Funston. 2009. Winter grazing system and supplementation during late gestation influence performance of beef cows and steer progeny. J. Anim. Sci. 87:1147–1155.

Loerch, S.C. 1996. Limit-feeding corn as an alternative to hay for gestating beef cows. J. Anim. Sci. 74:1211-1216.

Loy, T. W., T. J. Klopfenstein, G. E. Erickson, C. N. Macken and J. C. MacDonald. 2008. Effect of supplemental energy source and frequency on growing calf performance. J. Anim. Sci. 86:3504-3510.

Martin, J. L., K. A. Vonnahme, D. C. Adams, G. P. Lardy, and R. N. Funston. 2007. Effects of dam nutrition on growth and reproductive performance of heifer calves. J. Anim. Sci. 85:841–847.

Miller, A. J., D. B. Faulkner, R. K. Knipe, D. R. Strohbehn, D. F. Parrett, and L. L. Berger. 2001. Critical control points for profitability in the cow-calf enterprise. Prof. Anim. Sci. 17:295-302.

Miller, A. J., D. B. Faulkner, T. C. Cunningham, and J. M. Dahlquist. 2007. Restricting time of access to large round bales of hay affects hay waste and cow performance. Prof. Anim. Sci. 23:366-372.

NRC. 1970. The Nutrient Requirements of Domestic Animals. No. 4. Nutrient Requirements of Beef Cattle. National Research Council, Washington, D.C.

NRC. 1985. Nutrient Requirements of Sheep. 6th rev. ed. Natl. Acad. Press, Washington, DC.

NRC. 1996. Nutrient requirements of beef cattle. 7th rev. ed. Ed. Natl. Acad. Press, Washington, DC.

Olson, K. C., R. C. Cochran, T. J. Jones, E. S. Vanzant, E. C. Titgemeyer, and D. E. Johnson. 1999. Effects of ruminal administration of supplemental degradable intake protein and starch on utilization of low-quality warm-season grass hay by beef steers. J. Anim. Sci. 77:1016–1025.

Radunz, A. E., F. L. Fluharty, M. L. Day, H. N. Zerby, and S. C. Loerch. 2010a. Prepartum dietary energy source fed to beef cows: I. Effects on pre- and postpartum cow performance. J. Anim. Sci. 88:2717–2728.

Radunz, A. E., F. L. Fluharty, H. N. Zerby, and S. C. Loerch. 2011b. Winter-feeding systems for gestating sheep I. Effects on pre- and postpartum ewe performance and lamb progeny preweaning performance. J. Anim. Sci. 89:467–477.

Radunz, A. E., F. L. Fluharty, I. Susin, T. L. Felix, H. N. Zerby, and S. C. Loerch. 2011. Winter-feeding systems for gestating sheep II. Effects on feedlot performance, glucose tolerance, and carcass composition of lamb progeny. J. Anim. Sci. 89:478–488.

Rhind, S. M., M. T. Rae, and A. N. Brooks. 2001. Effects of nutrition and environmental factors on the fetal programming of the reproductive axis. Reproduction 122:205– 214.

Richards, M. W., J. C. Spitzer and M. B. Warner. 1986. Effect of varying levels of postpartum nutrition and body condition at calving on subsequent reproductive performance in beef cattle. J Anim. Sci. 62:300-306.

Sainz, R. D. and B. E. Bentley. 1997. Visceral organ mass and cellularity in growth-restricted and refed beef steers. J. Anim. Sci. 75:1229-1236.

Schoonmaker, J.P., S. C. Loerch, J. E. Rossi and M. L. Borger. 2003. Stockpiled forage or limit-fed corn as alternatives to hay for gestating and lactating beef cows. J. Anim. Sci. 81:1099-1105.

Shike, D. W., D. B. Faulkner, M. J. Cecava, D. F. Parrett, and F. A. Ireland. 2007. Effects of weaning age, creep feeding, and type of creep on steer performance, carcass traits, and economics. Prof. Anim. Sci. 23:325-332.

Shike, D.W., D. B. Faulkner, D. F. Parrett, and W. J. Sexten. 2009. Influences of corn co-products in limit-fed rations on cow performance, lactation, nutrient output, and subsequent reproduction. Prof. Anim. Sci. 25:132-138.

Smith, S. B., and J. D. Crouse. 1984. Relative contributions of acetate, lactate and glucose to lipogenesis in bovine intramuscular and subcutaneous adipose tissue. J. Nutr. 114:792–800.

Spitzer, J. C., D. G. Morrison, R. P. Wettemann and L. C. Faulkner. 1995. Reproductive responses and calf birth and weaning weights as affected by body condition at parturition and postpartum weight gain in primiparous beef cows. J. Anim. Sci. 73:1251-1257.

Stalker, L. A., D. C. Adams, T. J. Klopfenstein, D. M. Feuz, and R. N. Funston. 2006. Effects of pre- and postpartum nutrition on reproduction in spring calving cows and calf feedlot performance. J. Anim. Sci. 84:2582–2589.

Underwood, K. R. 2007. Gestational nutrient restriction effects on steer carcass and muscle characteristics. MS Thesis. Univ. of Wyoming, Laramie.

Underwood, K. R., J. F. Tong, J. M. Kimzey, P. L. Price, E. E. Grings, B. W. Hess, W. J. Means, and M. Du. 2008. Gestational nutrition affects growth and adipose tissue deposition in steers. Proc. Western Sec. Am. Soci. Anim. Sci. 59:29–32.

Vonnahme, K. A., M. J. Zhu, P. P. Borowicz, T. W. Geary, B. W. Hess, L. P. Reynolds, J. S. Caton, W. J. Means and S. P. Ford. 2007. Effect of early gestational undernutrition on angiogenic factor expression and vascularity in the bovine placentome. J. Anim. Sci. 85:2464-2472.

Wertz, A. E., L. L. Berger, P. M. Walker, D. B. Faulkner, F. K. McKeith, and S. L. Rodriguez-Zas. 2002. Early-weaning and postweaning nutritional management affect feedlot performance, carcass merit, and the relationship of 12th-rib fat, marbling score, and feed efficiency among Angus and Wagyu heifers. J. Anim. Sci. 80:28–37.

Zhu, M. J., S. P. Ford, W. J. Means, B. W. Hess, P. W. Nathanielsz, and M. Du. 2006. Maternal nutrient restriction affects properties of skeletal muscle in offspring. J. Physiol. 575:241–250.

CHAPTER 2

INFLUENCE OF PREPARTUM DIET TYPE ON COW PERFORMANCE AND SUBSEQUENT CALF PERFORMANCE

Abstract

Spring-calving, mature Angus, Simmental, and Simmental x Angus cows (n = 191) were utilized to evaluate the effects of prepartum diet type on cow and subsequent calf performance. Cows were blocked by BW and calving date into 16 pens and allotted to isocaloric, isonitrogenous dietary treatments: corn coproducts and ground cornstalks (COP) or ground hay (Hay). Treatment diets were fed from 90d prepartum to calving. All cows were fed a common diet postpartum. Cow BW and BCS were taken at beginning of feeding period, calving, and breeding. Calf BW was taken at birth and 56d intervals from the average calving date. Milk production was determined utilizing the weigh-suckle-weigh technique on d56 and d112. On d112, steers (n = 64) and non-replacement heifer calves (n = 23) were weaned and placed on a common feedlot diet with individual feed intake monitored using GrowSafe. Feedlot calves were harvested at a commercial facility when ultrasound 12th rib fat thickness (BF) reached 1.2 cm. Initial cow BW and BCS were not different ($P > 0.92$). At calving, cow BW trended higher (P = 0.08) and BCS was greater ($P < 0.01$) for COP cows. For COP, trends for increased calf birth BW ($P = 0.06$) and calves born dead ($P = 0.08$) coincided with numerically lower unassisted births ($P = 0.13$). Hay fed cows also tended to be lighter ($P = 0.07$) at breeding with lower BCS ($P = 0.05$); nevertheless, overall conception rate was not different ($P = 0.83$). No differences ($P \geq$ 0.42) in milk production were detected. Weaning BW, final BW, and days on feed were not different ($P \geq 0.19$); and as result, no difference ($P = 0.68$) in feedlot ADG was detected. Feedlot

DMI and G:F were not different ($P \geq 0.48$) across treatments. Calf health was monitored with no differences ($P \geq 0.71$) in mortality observed. No differences ($P \geq 0.45$) were detected for HCW, LMA, BF, marbling score, yield grade, or KPH. No differences ($P \geq 0.32$) in quality or yield grade distribution were observed. Prepartum cow diets, differing in energy source and protein type, formulated to be isocaloric and isonitrogenous do not affect performance and carcass traits of subsequent offspring.

Key Words: cow gestation fetal programming

Introduction

Feed costs account for the greatest share of input costs for the cow/calf producer (Miller et al., 2001). This is especially true during the winter months as the majority of the nutrients consumed by the cow must be supplied through stored feeds. Thus, the development of cost effective wintering strategies that are effective in maintaining body condition of beef cows is of great importance. Traditionally, cows have been maintained by feeding ad libitum hay. Increasing hay and grain prices have led producers to search for alternate cow feeding strategies. The rapid expansion of the ethanol industry has resulted in increased availability of corn coproducts. Corn coproducts offer excellent sources of protein and energy when formulating ruminant diets (Klopfenstein et al., 2008; Green et al., 1987). Limit-fed diets utilizing corn coproducts and low quality forages, such as cornstalks, have been proven to be effective in maintaining cow performance while being less expensive than hay (Shike et al., 2009; Braungardt et al., 2010).

The fetal programming concept states that maternal nutrition can have long-lasting, significant influences on the life of subsequent progeny. Previous research (Stalker et al., 2006;

Larson et al., 2009) determined that improved nutrition during late gestation of cows grazing dormant, winter pastures has the potential to improve pre- and post-weaning productivity of resulting steer progeny. There is limited data evaluating the effects of feeding corn coproducts in late gestation maternal diets on subsequent calf performance. The objectives of the current study were to evaluate the influence of isocaloric and isonitrogenous diets of differing energy and protein types on not only cow performance, but on performance and carcass characteristics of subsequent progeny.

Materials and Methods

Experimental Animals

Spring-calving, pregnant, mature Angus, Simmental, and Simmental x Angus cows (n = 191; BW = 678 ± 71 kg; age = 4.1 ± 2.0 yr.) and their progeny were utilized to evaluate the effects of winter diet type on cow performance as well as the pre-weaning and post-weaning performance of subsequent progeny. Cows were maintained at the Orr Beef Research Center in Baylis, IL. Experimental animals were managed according to the guidelines recommended in the Guide for the Care and Use of Agriculture Animals in Agriculture Research and Teaching (Consortium, 1988). All experimental procedures followed were approved by the University of Illinois Institutional Animal Care and Use Committee.

Experimental Design

A randomized complete block design was applied to the 191 cows. Cows were blocked by expected calving date and BW. The early calving block consisted of cows confirmed pregnant to synchronized artificial insemination (AI). The late calving block consisted of cows that conceived one estrus cycle later to either AI or clean-up bulls. The early calving block utilized

136 cows, with 55 cows in the late calving block. Within calving block, cows were then blocked into heavy and light weight blocks of 636 kg or 727 kg BW, respectively. Within block, cows were stratified by breed and then allotted to 16 pens, with 8 pens total per treatment. Twelve pens (6 per treatment) contained 10 cows and 4 pens (2 per treatment) contained 17 or 18 cows. Pens were randomly assigned to treatment.

Management and Diets

Cows were placed on one of two dietary treatments (Table 1): limit-fed ground grass hay (Hay, n = 96) or limit-fed corn coproducts and ground cornstalks (COP, n = 95) 90d prior to expected calving date. Hay treatment was 100% ground grass hay. The COP diet consisted of 60.4% ground cornstalks, 23.7% corn bran, and 15.9% dried distillers grains plus solubles (DDGS). Nutrient analysis of feedstuffs utilized in treatment diets is shown in Table 2; diet dry matter intake and nutrient composition are shown in Table 3. Tabular values from NRC (1996) were used for corn coproducts when formulating dietary treatments. Treatment diets were balanced for TDN, CP, calcium, and phosphorus. Treatment diets were formulated to be isocaloric and isonitrogenous and meet NRC (1996) nutrient requirements of 636 kg or 727 kg cows with 9.1 kg milk at peak milk production. Feeding level of treatment diets was increased each 30d of the prepartum feeding period to reflect changing nutrient requirements of cows during late gestation. Cows were provided a complete mineral ad libitum. Cows remained on treatment diets until calving. Following calving, all cows were comingled and limit-fed a common diet comprised of ground cornstalks and corn coproducts.

During the prepartum feeding period and early lactation, cows were maintained in either 11.0 x 10.7 m or 16.9 x 48.8 m concrete lots with a 7.3 x 7.3 m or 3 x 6 m open-front shed, respectively. Cows were provided with a minimum of 0.73 m of fence-line bunk space regardless of pen size. Average expected calving date and actual average calving dates were 2/6/2010 and 2/4/2010 ± 11d, respectively. In the spring, cow/calf pairs were rotated through mixed pastures of orchardgrass (*Dactylis glomerata L*.), endophyte infected tall fescue (*Festuca arundinacea*), red clover (*Trifolium pretense*), and bluegrass (*Poa pratensis L*.).

Steer and non-replacement heifer calves (n = 91; Hay = 45, COP = 46; 66 steers, 25 heifers) were early weaned at 112d following average expected calving data and transported via commercial trucking to the Beef and Sheep Field Laboratory, Urbana, IL for the duration of finishing period. Calves were vaccinated with the following: Bovishield Gold FP5 L5 HB (Pfizer, Exton, PA), given for prevention of infectious bovine rhinotracheitis, bovine viral diarrhea types 1 and 2, parainfluenza-3, bovine respiratory syncytial virus, and leptospirosis; One Shot Ultra 7 (Pfizer, Exton, PA) for prevention of blackleg, malignant edema, black disease, gasgangrene, enterotoxemia and enteritis, and bovine pneumonia; Pulmo-Guard MpB (AgriLabs, St Joseph, MO) given for the prevention of *mycoplasm bovis*. Calves were dewormed with Eprinex (Merial, Duluth, GA) pour-on and equipped with an electronic identification tag. Upon entry to the feedlot, calves were adapted to a common, ad libitum finishing diet (Table 4) over a transition period of 20d. During the finishing period, calves were split by sex with maternal treatments comingled. Calves were implanted with Component EC (10 mg estradiol benzoate, 100 mg progesterone, 29 mg tylosin 99 tartate; VetLife, Overland Park, KS) 28d post-weaning and received a Compudose 200 implant (25.7 mg estradiol; VetLife, Overland Park, KS) 71d later.

Cow Performance Data Collection

Full BW was taken on 2 consecutive days at the start of the prepartum feeding period for initial BW. Cow BCS was also taken at this time by trained University of Illinois personnel. Within 48h of calving, cow BW and BCS was taken to evaluate cow performance at the end of the treatment period. Cow BW at calving did not account for loss of calf and placental membranes. Calving data and incidence of dystocia was reported for all calves (n = 194) born to cows started on prepartum treatment diets. Milk production was estimated for all cows with calves utilizing a weigh-suckle-weigh technique (Boggs at al., 1980) 56d and 112d after average expected calving date. At rebreeding, cows were synchronized using a CoSynch + CIDR protocol (Bremer et al., 2004) and were artificially inseminated in two groups on consecutive days at an average of 82 ± 19d postpartum. Cow BW and BCS were taken at time of CIDR removal to evaluate lasting effects of dietary treatments. Following AI, all cows went to pasture and were exposed to clean-up bulls for two subsequent estrus cycles. Conception rates for AI were determined via transrectal ultrasonography at 68 or 69d following insemination. Cow performance was reported for 163 cows and excluded those who lost calves (Hay, n = 6; COP, n = 10), twinned (Hay, n = 2; COP, n = 2), failed to calve (Hay, n = 0; COP, n = 1), had injured calves prior to breeding (Hay, n = 1; COP, n = 2), or died (Hay, n = 3; COP, n = 1) over the course of the study. Reproductive data was reported for 157 cows as additional cows were culled prior to breeding (Hay, n = 2; COP, n = 4).

Pre-weaning Calf Performance Data Collection

Calf BW was taken within 48hr of birth. Calf BW was taken in 56d intervals from the average expected calving date. On d112, all calves were weighed to measure pre-weaning calf ADG. Incidence of pre-weaning morbidity treatment was recorded by animal care personnel. Pre-weaning calf performance was reported for all calves (n = 161, 66 steers, 69 heifers, 26 bulls) born to cows placed on dietary treatments, minus twins and those injured or deceased prior to d112. Number of male calves left intact as bulls was equal by treatment.

Post-weaning Calf Performance Data Collection

Initial BW entering the feedlot was the BW measurement of the early weaned calves taken on d112. Throughout the finishing phase, collection of calf BW in 56d intervals was continued. Individual feed intake was monitored using the GrowSafe automated feeding system (Model 4000E, GrowSafe Systems Ltd., 86 Airdrie, Alberta, Canada) during the finishing period. Animal intakes were audited daily by trained personnel. Feed intake data was considered acceptable if at least 85% of feed supplied to the bunk was accounted for and 90% of feed consumed was assigned to an individual ID. Data was also considered acceptable if 95% of the data sent from the weight panel was received at the computer compared to all data points sent for a 24 hour period. Also, 95% of the data from an individual electronic identification tag needed to be received at the computer compared to all possible data sent from the electronic identification panel. A log was kept for repair or replacement of component parts and data was subsequently discarded that day for the affected pens. The GrowSafe system has been validated and is a viable method for obtaining individual feed intake (Basarab et al., 2003; Nkrumah et al., 2004; Lancaster et al., 2009). Incidence of morbidity treatment during the finishing phase was recorded by animal care staff. Cattle were harvested when 12^{th} rib backfat thickness (BF) reached 1.2 cm, in such a way that cattle were harvested in 4 groups. Ultrasound measurements were taken with an Aloka 500SV (Wallingford, CT) B-110 mode instrument equipped with a 3.5-MHz general purpose transducer array. Backfat measurements were taken in a transverse orientation between the 12th and 13th ribs approximately 10 cm distal from the midline. Ultrasound images were processed utilizing CPEC ultrasound imaging software (Cattle Performance Enhancement Company LLC., Oakley, KS). Final BW was calculated from HCW using a standard dressing percentage of 63%. Post-weaning performance was excluded for 5 calves (Hay, n = 3; COP, n = 2) due to injury or mortality.

Carcass Data Collection

Upon reaching the target BF, cattle were transported via commercial trucking to be harvested at a commercial facility (Tyson Fresh Meats, Joslin, IL). Trained University of Illinois personnel collected harvest day data (harvest order, and HCW). Carcass measurements were taken following a 24hr carcass chill with Video Image Analysis (VIA) with the USDA camera system and were obtained from Tyson Fresh Meats, Joslin, IL. Carcass measurements of one animal, COP, were excluded because of an in-plant error during data collection.

Feed Cost Calculations

Average price data for 2011 was utilized when calculating treatment diet feed costs to reflect increasing feed prices. Ingredient price for hay was collected from the National Agricultural Statistics Service (NASS, 2011). Ingredient price for cornstalks was calculated using the Corn Stover Pricer (Edwards et al., 2012a). An additional $8.82/1000 kg was added to the ingredient cost of hay and cornstalks to account for the added cost of grinding forages

(Edwards et al., 2012b). Average 2011 prices for DDGS and corn bran were attained from Dakota Gold Research Association (Sioux Falls, SD; K. Karges, personal communication). Average prices (DM basis) for feedstuffs used to calculate feed costs were: ground hay, \$0.16/kg; ground cornstalks, \$0.08/kg; DDGS, \$0.22/kg; and corn bran, \$0.15/kg. Reported treatment DMI and average daily feed costs are the averages of the values for each BW block, as cows were blocked by BW equally within treatment.

Statistical Analysis

Treatment effects were considered significant at an α level of 0.05, a trend was defined at an α level of 0.10. Non-categorical data was analyzed using the MIXED procedure of SAS (SAS Inst. Inc., Cary, NC). Categorical data was analyzed using the GENMOD procedure of SAS. The least square means function of SAS was used to separate treatment means. Treatment pen was used as the experimental unit for cow performance data including measurement of BW, BCS, and milk production. Individual animal was used as the experimental unit for all other response variables. Calf sex was used as a covariate for the analysis of calving information, pre-weaning and feedlot calf performance, and carcass characteristics.

Results and Discussion

Cow Performance

Cow BW, BCS, and calving data are shown in Table 5. By design, cow BW at the beginning of the prepartum feeding period was not different ($P = 0.93$) among treatments. Also, BCS was not different ($P = 0.92$) for Hay and COP cows. Coproduct fed cows calved with a trend for higher BW (P = 0.08) and greater BCS ($P = 0.002$) was observed. Greater weight loss when cows are maintained on ad libitum forage diets relative to those limit-fed DDGS/cornstalk diets has been observed in previous research (Braungardt et al., 2010; Kovarik et al., 2009). Differences in BW loss could result from additional fat of corn coproducts or energy repartitioning due to the increased RUP found in the COP treatment (Shike et al., 2009). Sainz and Bentley (1997) determined that maintenance requirements are lower for limit-fed animals when compared to ad libitum feeding due to reduced visceral mass. Decreased maintenance requirement increases available nutrients for bodily reserves, and could account for the trend for heavier calving BW and significant BCS difference observed for COP fed cows. The energy content of DDGS when incorporated into the forage-based diets of heifers has been determined to be greater than previously estimated by the NRC (1996; Loy et al., 2008).

Calf birth BW tended to be heavier ($P = 0.06$; Table 6) when cows were fed COP. Calving data are shown in Table 7. For COP cows, a trend for a greater number of calves born dead ($P = 0.08$) coincides with a numerically lower percentage of unassisted births when compared to Hay cows. The observation of increased incidence of dystocia was unexpected and does raise some concern when feeding corn coproducts in the diets of gestating beef cows. Increased calf loss during calving may be partially attributed to available labor at calving; yet, a treatment bias is apparent. Increased calf birth BW has been previously observed (Loerch, 1996; Radunz et al., 2010) when beef cows are limit-fed substantial levels of concentrate, corn or DDGS, during late gestation; however, no differences in dystocia were previously observed. Birth BW may be increased by elevated fetal glucose supply when concentrates are fed to dams. Spitzer et al. (1995) observed increased birth BW when calving BCS was elevated from 4 to 6. Calving BCS for COP cows was one third of a score higher than for Hay cows.

Greater body condition ($P = 0.05$) of COP persisted at calving as BW trended higher ($P = 0.07$). Data for cow reproduction are shown in Table 8. Treatment diets had no effect ($P \geq 0.62$)

on either AI or overall conception rates. Richards et al. (1986) indicated that if a minimum calving BCS of 5 is achieved, additional BCS beyond 5 does not improve reproductive rates. A calving BCS of at least 5 was achieved for both dietary treatments in the current study. Milk production was not different ($P \geq 0.42$) by dietary treatment whether measured at 56 or 112d.

Calf Performance

Pre-weaning calf performance data are shown in Table 6 and post-weaning performance data are shown in Table 9. Calf health data are shown in Table 10. As previously discussed, calf birth BW trended greater ($P = 0.06$) for COP cows relative to hay. However, this trend for increased calf BW did not continue as BW was not different ($P = 0.\ 95$) at time of early weaning. No difference ($P = 0.33$) in pre-weaning ADG was detected. Spitzer et al. (1995) concluded that, despite differences in birth BW, weaning BW is more heavily influenced by milk production than maternal bodily reserves at calving. This would agree with the results of the current study in which milk production was similar for Hay and COP fed cows with no differences in weaning BW detected. In contrast, Larson et al. (2009) observed no differences in milk production when cows grazing dormant, native range pastures received no supplement or were offered CP supplement; however, calf weaning BW was increased with CP supplementation.

Initial feedlot BW and final BW were not different ($P \geq 0.27$) among treatments. Days on feed were not different ($P = 0.19$) for both Hay and COP, resulting in no difference ($P = 0.68$) for feedlot ADG. Feedlot DMI was not different ($P = 0.48$) and no differences ($P = 0.67$) in feedlot gain efficiency were observed. Data is in-conclusive concerning the post-weaning growth rate of steer progeny born to grazing cows on differing planes of nutrition during late gestation. Stalker et al. (2006) observed no effects of additional CP supplement on post-weaning

ADG, DMI, efficiency of gain, and final BW. In contrast, Larson et al. (2009) detected trends for steers gestated by dams receiving CP supplement to have increased ADG and final BW. Differences in calf performance for the two supplementation studies may be attributed to supplement RUP concentration, which is greater in the supplement fed by Larson et al. (2009). However, RUP from supplement was similar for both studies. It is difficult to compare the results realized by Larson et al. (2009) or Stalker et al. (2006) and those of the current study as management conditions, environment, and nutrient status of cows and calves used in the two studies are not similar. There is limited data evaluating the fetal programming effects of feeding corn coproduct/cornstalk diets, or other wintering diet types, to beef cows maintained in drylots.

Incidence of morbidity from birth to weaning was not different (P = 0.71) by treatment. Pre-weaning morbidity was increased in calves born to cows that had been restricted to 70% of NRC nutrient requirement for the last 100d of gestation (Corah et al., 1975). Immunoglobulin transfer in neonate lambs is enhanced or decreased when dams are undernourished or overfed, respectively (Hammer et at al., 2007). Research indicates that maternal nutrition affects the development of bodily systems that influence the incidence of bovine respiratory disease later in life (Funston et al., 2010). When grazing cows are offered CP supplement during late gestation, it has been observed that a decreased percentage of steer progeny have required treatment for respiratory disease in the feedlot (Larson et al., 2009). In the current study, feedlot morbidity was not different (P = 0.76) by maternal diet type.

Carcass Evaluation

Carcass characteristics are shown in Table 11. As foreshadowed by previous feedlot performance, HCW was similar (P = 0.70) for calves from Hay and COP cows. No differences

(P = 0.82) were observed for BF. No difference in BF was expected since calves were harvested upon reaching a target BF of 1.2 cm. Longissimus muscle area and KPH was not affected ($P \geq$ 0.65) by maternal dietary treatment. There is evidence that the timing of maternal dietary manipulation influences development of fetal skeletal muscle and adipose tissues (Du et al., 2010). When maternal dietary treatments were initiated during mid-gestation, Radunz et al. (2011) observed decreased LMA and reduced visceral adiposity of lambs when ewes were fed DDGS instead of corn or haylage. Neither average yield grade nor marbling score was different ($P \geq 0.45$) whether calves were gestated by Hay or COP cows. Conflicting data exists on the efficacy of prepartum CP supplementation on the carcass characteristics of subsequent progeny. Stalker et al. (2006) observed no effects of maternal supplementation on steer carcass characteristics; yet, when a CP supplement with increased RUP concentration was fed to cows under similar conditions by (Larson et al. (2009), marbling scores were improved in subsequent steer progeny. Calves developing and growing in utero are not solely influenced by maternal diet during gestation, but are indirectly supplied by the dam's bodily reserves accumulated over time. Historically, the herd in which the current study was conducted is maintained in adequate body condition (Braungardt et al., 2010; Shike et al., 2009). Perhaps, the lack of differences observed in calf performance or carcass characteristics indicates that susceptibility to adverse effects of short term maternal nutritional insults may be lessened by sufficient nutrition over the long term.

Cow Feed Costs

The diet costs are shown in Table 1. The COP diet was \$0.03/kg DM less expensive than hay. Average DMI of the entire prepartum feeding period for Hay and COP treatments were 12.0 and 10.4 kg, respectively. Average daily feed cost of Hay was \$1.87/cow$\cdot$d^{-1}, with COP costing \$1.31/cow·d^{-1}. Cows fed COP were able to maintain BCS more effectively than Hay fed cows while consuming less DM at a lower cost to the cow/calf producer. Feed costs have risen significantly in recent years, yet wintering cows on corn coproduct/cornstalk diets remains to be a cost effective feeding strategy when compared to hay feeding.

Conclusions

When diets are formulated to be isocaloric and isonitrogenous, slight increases in BW and BCS for limit-fed corn coproduct/cornstalks fed cows was observed when compared to limit-feeding hay. However, both diet types maintained adequate levels of cow performance during gestation. These data indicate that maternal diet type during late gestation has limited effects on the growth performance and carcass characteristics of subsequent offspring when diets are formulated to meet energy and protein requirements. Feed costs were decreased when corn coproducts and cornstalks were incorporated into the diets of gestating beef cows. Thus, when formulated to meet energy and protein requirements, winter feeding strategy can be determined based off of feed costs without adverse effects on subsequent progeny.

Tables

Table 1. Composition of treatment diets.

Item	Treatment[1, 2]	
	Hay	COP[3]
Ground hay, % DM	100	--
Ground cornstalks, % DM	--	60.4
DDGS[4], % DM	--	23.7
Corn bran[5], % DM	--	15.9
Diet cost[6], $/kg DM	0.16	0.13

[1]Hay = ad libitum fed hay; COP = limit-fed corn coproducts and ground cornstalks

[2]Both treatments given ad libitum access to mineral: Salt = 20.08%, Ca = 16.13%, P = 8.17%, Mg = 2.32%, K = 2.32%, S = 0.20%, Co = 10 ppm, I = 48 ppm, Cu = 1,498 ppm, Fe = 8 ppm, Mn = 2,017 ppm, Se = 30 ppm, Zn = 3026 ppm, vitamin A = 92 kIU/kg, vitamin D = 18 IU/kg, vitamin E = 458 IU/kg

[3]COP diet contained 0.05 kg/cow$\cdot$day^{-1} ground limestone

[4]Dried Distillers Grains plus Solubles

[5]Dakota Bran (Dakota Gold Research Association)

[6]Feed costs calculated using the following prices (DM Basis): ground hay, $0.16/kg; ground cornstalks, $0.08/kg; DDGS, $0.22/kg; and corn bran, $0.15/kg.

Table 2. Nutrient composition of feed ingredient used in treatment diets[1].

Ingredient	CP, %	ADF, %	NDF, %	TDN, %	Fat, %	S, %	K, %	Ca, %	P, %
Ground hay	9.46	45.50	67.01	55.7	2.29	0.15	1.51	0.35	0.20
Ground cornstalks	3.76	54.04	81.39	49.0	2.96	0.05	0.83	0.37	0.07
DDGS[2]	28.00	14.66	38.66	88.0	8.25	0.61	1.24	0.15	0.83
Corn bran[3]	12.84	7.29	22.75	88.0	8.43	0.73	1.45	0.09	0.85

[1]Nutrient composition presented on a DM basis

[2]DDGS = Dried Distillers Grains plus Solubles, TDN value from NRC (1996)

[3]Dakota Bran (Dakota Gold Research Association), TDN value used for DDGS in NRC (1996)

Table 3. Dry matter intake and nutrient composition of treatment diets.

Item	Treatment[1]					
	Hay			COP		
Day of treatment period	1 to 30	31 to 60	61 to calving	1 to 30	31 to 60	61 to calving
	Light Block[2]					
DMI, kg	10.6	11.3	12.5	9.2	9.8	10.8
TDN, kg	5.9	6.3	7.0	5.9	6.3	7.0
CP, kg	1.0	1.1	1.2	1.0	1.1	1.2
Ca, g	41.25	44.01	48.50	40.61	42.35	45.03
P, g	19.57	20.88	23.01	32.54	34.76	38.25
	Heavy Block[3]					
DMI, kg	11.6	12.4	13.7	10.1	10.7	11.8
TDN, kg	6.5	6.9	7.6	6.5	6.9	7.6
CP, kg	1.1	1.2	1.3	1.1	1.2	1.3
Ca, g	45.22	48.25	53.17	43.04	44.85	47.84
P, g	21.45	22.89	25.22	35.68	38.02	41.88

[1]Hay = ad libitum fed hay; COP = limit-fed corn coproducts and ground cornstalks
[2]Formulated to meet nutrient requirements of 636 kg cows with 9.1 kg peak milk production
[3]Formulated to meet nutrient requirements of 727 kg cows with 9.1 kg peak milk production

Table 4. Composition of common feedlot diet

Item	Inclusion, % DM
Wet corn gluten feed	38.500
High moisture corn	33.500
Corn husklage	20.000
Ground corn	6.497
Lime	1.200
Liquid fat	0.120
Trace mineral salt[1]	0.080
Urea	0.067
Rumensin 80[2]	0.009
Vitamin A, D, E[3]	0.008
Thiamine	0.008
Tylan 40[4]	0.007
Copper sulfate	0.004

[1]Salt = 80%, Fe = 2.57%, Zn = 2.86%, Mn = 5,710 ppm, Cu = 2,290 ppm, I = 100 ppm, Se = 86 ppm
[2]Rumensin 33g/1000kg
[3]Vitamin A = 363 IU/kg, vitamin D = 36 IU/kg, vitamin E = 5 IU/kg
[4]Tylan 40 11g/1000kg

Table 5. Influence of prepartum diet type on cow BW, BCS, and milk production.

	Treatment[1]			
Item	Hay	COP	SEM	*P*-value
Pens	8	8		
BW, kg				
Initial	669	672	20	0.93
Calving	593	641	18	0.08
Breeding	560	604	16	0.07
BCS				
Initial	6.0	6.0	0.1	0.92
Calving	5.1	5.4	0.1	0.002
Breeding	4.9	5.1	0.1	0.05
56d 24-h milk, kg	8.8	9.5	0.6	0.45
112d 24-h milk, kg	10.1	10.8	0.7	0.42

[1]Hay = ad libitum fed hay; COP = limit-fed corn coproducts and ground cornstalks

Table 6. Influence of prepartum diet type on calf pre-weaning performance.

	Treatment[1]			
Item	Hay	COP	SEM	*P*-value
Calves	82	79		
Calf birth date, Julian d	34.1	35.1	1.1	0.51
BW, kg				
Birth	39	40	1	0.06
Weaning[2]	164	164	2	0.95
ADG	1.02	1.00	0.01	0.33

[1]Hay = ad libitum fed hay; COP = limit-fed corn coproducts and ground cornstalks
[2]Weaning BW taken on d112

Table 7. Influence of prepartum diet type on calving.

Item	Item	Item	Item
Calves	Calves	Calves	Calves
Unassisted births, %	Unassisted births, %	Unassisted births, %	Unassisted births, %
Dead on arrival, %	Dead on arrival, %	Dead on arrival, %	Dead on arrival, %

[1]Hay = ad libitum fed hay; COP = limit-fed corn coproducts and ground cornstalks

Table 8. Influence of prepartum diet type on subsequent reproduction.

	Treatment[1]		
Item	Hay	COP	*P*-value
Cows	82	75	
A.I. conception, %	42	45	0.62
Overall conception, %	89	87	0.83

[1]Hay = ad libitum fed hay; COP = limit-fed corn coproducts and ground cornstalks

Table 9. Influence of prepartum diet type on calf post-weaning performance.

	Treatment[1]			
Item	Hay	COP	SEM	*P*-value
Calves	42	45		
Initial BW[2], kg	164	159	3	0.27
Final BW[3], kg	563	557	10	0.70
Days on feed	275	284	5	0.19
ADG, kg	1.44	1.42	0.03	0.68
DMI, kg	8.6	8.4	0.1	0.48
G:F	0.168	0.170	0.003	0.67

[1]Hay = ad libitum fed hay; COP = limit-fed corn coproducts and ground cornstalks
[2]BW taken on d112
[3]HCW/standard dressing percent (63%)

Table 10. Influence of prepartum diet type on calf health.

	Treatment[1]		
Item	Hay	COP	*P*-value
Pre-weaning[2]			
Morbidity, %	11.8	10.1	0.71
Mortality, %	3.2	2.2	0.69
Feedlot[3]			
Morbidity, %	20.8	23.4	0.76
Mortality, %	2.1	2.1	0.99

[1]Hay = ad libitum fed hay; COP = limit-fed corn coproducts and ground cornstalks

[2]Percentage of calves treated during the pre-weaning period; Hay, n = 93; COP n = 89

[3]Percentage of calves treated during the post weaning period; Hay, n = 42; COP, n = 45

Table 11. Influence of prepartum diet type on calf carcass characteristics.

	Treatment[1]			
Item	Hay	COP	SEM	*P*-value
Calves	42	44		
HCW, kg	355	351	6	0.70
12th-rib fat thickness, cm	1.2	1.2	0.1	0.82
KPH, %	2.1	2.1	0.1	0.65
LM Area, cm^2	81.6	81.2	1.0	0.78
Avg. Yield Grade	3.1	3.1	0.1	0.95
Marbling Score[2]	534	517	16.6	0.45

[1]Hay = ad libitum fed hay; COP = limit-fed corn coproducts and ground cornstalks
[2]400-499 = Small, 500-599 = Modest, 600-699 = Moderate, 700-799 = Slightly Abundant

Literature Cited

Basarab, J. A., M. A. Price, J. L. Aalhus, E. K. Okine, W. M. Snelling, and K. L. Lyle. 2003. Residual feed intake and body composition in young growing cattle. Can. J. Anim. Sci. 83:189–204.

Boggs, D. L., E. F. Smith, R. R. Schalles, B. E. Brent, L. R. Corah, and R. J. Pruitt. 1980. Effects of milk and forage intake on calf performance. J. Anim. Sci. 51:550-553.

Braungardt, T. J., D. W. Shike, D. B. Faulkner, K. Karges, M. Gibson, and N. M. Post. 2010. Comparison of corn coproducts and corn residue bales with alfalfa mixed hay on beef cow-calf performance, lactation, and feed costs. Prof. Anim. Sci. 26:356-364.

Bremer, V. R., S. M. Damiana, F. A. Ireland, D. B. Faulkner, and D. J. Kesler. 2004. Optimizing the interval from PGF to timed AI in the CoSynch+CIDR and 7–11 estrus synchronization protocols for postpartum beef cows. J. Anim. Sci. 82(Suppl. 2):106. (Abstr.)

Consortium. 1988. Guide for the Care and Use of Agriculture Animals in Agriculture Research and Teaching. Consortium for Developing a Guide for the Care and Use of Agriculture Animals in Agriculture Research and Teaching, Am. Soc. Anim. Sci. Assoc. Headquarters, Savoy, IL.

Corah, L. R., T. G. Dunn, and C. C. Kaltenbach. 1975. Influence of prepartum nutrition on the reproductive performance of beef females and the performance of their progeny. J. Anim. Sci. 41:819-824.

Du, M., J. Tong, J. Zhao, K. R. Underwood, M. Zhu, S. P. Ford and P. W. Nathanielsz. 2010. Fetal programming of skeletal muscle development in ruminant animals. J. Anim. Sci. 88:E51-E60.

Edwards, W., S. Shouse, K. Jensen, T. Eggers, and D. Busby. 2012a. Corn Stover Pricer. Iowa St. Univ., Ames, IA. Available. www.extension.iastate.edu/agdm/.../a170cornstover pricer.xlsx. Accessed March 17, 2012.

Edwards, W., A. Johanns, and A. Chamra. 2012b. 2012 Iowa Farm Custom Rate Survey. Iowa St. Univ., Ames, IA. Available. http://www.extension.iastate.edu/agdm/crops/pdf/a3-10.pdf. Accessed: March 13, 2012.

Funston, R. N., D. M. Larson, K. A. Vonnahme. 2010. Effects of maternal nutrition on conceptus growth and offspring performance: Implications for beef cattle production. J. Anim. Sci. 88:E205-E215.

Green, D. A., R. A. Stock, F. K. Goedeken and T. J. Klopfenstein. 1987. Energy value of corn wet milling by-product feeds for finishing ruminants. J. Anim. Sci. 65:1655-1666.

Hammer, C. J., K. A. Vonnahme, J. B. Taylor, D. A. Redmer, J. S. Luther, T. L. Neville, J. J. Reed, J. S. Caton, and L. P. Reynolds. 2007. Effects of maternal nutrition and selenium supplementation on absorption of IgG and survival of lambs. J. Anim. Sci. 85 (Suppl. 1):391. (Abstr.)

Klopfenstein, T. J., G. E. Erickson and V. R. Bremer. 2008. Board-Invited Review: Use of distillers by-products in the beef cattle feeding industry. J. Anim. Sci. 86:1223-1231.

Kovarik, L. M., M. K. Luebbe, R. J. Rasby, and G. E. Erickson. 2009. Limit feeding beef cows with bunkered wet distillers grains plus solubles or distillers solubles. Univ. Nebr. Beef Rep. MP 528.

Lancaster, P. A., G. E. Carstens, F. R. B. Ribeiro, L. O. Tedeschi, and D. H. Crews, Jr. 2009. Characterization of feed efficiency traits and relationships with feeding behavior and ultrasound carcass traits in growing bulls. J. Anim. Sci. 87:1528–1539.

Larson, D. M., J. L. Martin, D. C. Adams, and R. N. Funston. 2009. Winter grazing system and supplementation during late gestation influence performance of beef cows and steer progeny. J. Anim. Sci. 87:1147–1155.

Loerch, S.C. Limit-feeding corn as an alternative to hay for gestating beef cows. 1996. J. Anim. Sci. 74:1211-1216.

Loy, T. W., T. J. Klopfenstein, G. E. Erickson, C. N. Macken and J. C. MacDonald. 2008. Effect of supplemental energy source and frequency on growing calf performance. J. Anim. Sci. 86:3504-3510.

Miller, A. J., D. B. Faulkner, R. K. Knipe, D. R. Strohbehn, D. F. Parrett, and L. L. Berger. 2001. Critical control points for profitability in the cow-calf enterprise. Prof. Anim. Sci. 17:295-302.

NASS. 2011. National Agricultural Statistics Survey. 2011. Agricultural Prices-Annual. Available. http://www.nass.usda.gov. Accessed: March 13, 2012.

Nkrumah, J. D., J. A. Basarab, M. A. Price, E. K. Okine, A. Ammoura, S. Guercio, C. Hansen, C. Li, B. Benkel, and S. S. Moore. 2004. Different measures of energetic efficiency and their relationships with growth, feed intake, ultrasound, and carcass measurements in hybrid cattle. J. Anim. Sci. 82:2451–2459.

NRC. 1996. Nutrient Requirements of Beef Cattle. 7th ed. Natl. Acad. Press, Washington, DC.

Radunz, A. E., F. L. Fluharty, M. L. Day, H. N. Zerby, and S. C. Loerch. 2010. Prepartum dietary energy source fed to beef cows: I. Effects on pre- and postpartum cow performance. J. Anim. Sci. 88:2717–2728.

Radunz, A. E., F. L. Fluharty, I. Susin, T. L. Felix, H. N. Zerby, and S. C. Loerch. 2011. Winter-feeding systems for gestating sheep II. Effects on feedlot performance, glucose tolerance, and carcass composition of lamb progeny. J. Anim. Sci. 89:478–488.

Richards, M. W., J. C. Spitzer and M. B. Warner. 1986. Effect of varying levels of postpartum nutrition and body condition at calving on subsequent reproductive performance in beef cattle. J Anim. Sci. 62:300-306.

Sainz, R. D. and B. E. Bentley. 1997. Visceral organ mass and cellularity in growth-restricted and refed beef steers. J. Anim. Sci. 75:1229-1236.

Shike, D.W., D. B. Faulkner, D. F. Parrett, and W. J. Sexten. 2009. Influences of corn co-products in limit-fed rations on cow performance, lactation, nutrient output, and subsequent reproduction. Prof. Anim. Sci. 25:132-138.

Spitzer, J. C., D. G. Morrison, R. P. Wettemann and L. C. Faulkner. 1995. Reproductive responses and calf birth and weaning weights as affected by body condition at parturition and postpartum weight gain in primiparous beef cows. J. Anim. Sci. 73:1251-1257.

Stalker, L. A., D. C. Adams, T. J. Klopfenstein, D. M. Feuz, and R. N. Funston. 2006. Effects of pre- and postpartum nutrition on reproduction in spring calving cows and calf feedlot performance. J. Anim. Sci. 84:2582–2589.